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UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF CALIFORNIA

UTSTARCOM, INC., Plaintiff, v. STARENT NETWORKS, CORP., Defendant.	Case No.: C04 01122 PVT **COMPLAINT FOR PATENT INFRINGEMENT AND DEMAND FOR JURY TRIAL**

Plaintiff UTStarcom, Inc. ("UTStarcom") for its complaint herein avers as follows:

JURISDICTION AND VENUE

1. This is an action for patent infringement arising under the patent laws of the United States, Title 35, United States Code.

2. This Court has subject matter jurisdiction over this action under 28 U.S.C. §§ 1331 and 1338(a).

3. Venue is proper in this judicial district pursuant to 28 U.S.C. §§ 1391(b), 1391(c) and 1400(b).

INTRADISTRICT ASSIGNMENT

Pursuant to Civil L.R. 3-2(c), this patent infringement action falls within an excepted category of actions and therefore may be assigned on a district-wide basis.

PLAINTIFF

4. UTStarcom is a corporation organized and existing under the laws of the State of Delaware, with a principal place of business and worldwide headquarters located in this judicial district at 1275 Harbor Bay Parkway, Alameda, California 94502.

5. UTStarcom is a leader in the global telecommunications market for wireless, wireline, optical, and access switching solutions. UTStarcom's customers include public telecommunications service providers that operate wireless voice and data networks throughout the world. UTStarcom designs, manufactures, sells, and installs wireless network solutions that enable wireless service providers to offer voice, data, and Internet access services rapidly and cost effectively.

6. In May 2003, UTStarcom acquired selected assets of 3Com's CommWorks division, formerly known as 3Com's Carrier Networks Business. UTStarcom acquired CommWorks' portfolio of carrier-focused voice and data products, customer support, professional services, and intellectual property.

7. The CommWorks group has been integrated into UTStarcom to expand UTStarcom's capabilities to produce specialized hardware and software used for wireless data transmission. UTStarcom is a leader in providing equipment for wireless transmission of data to cellular service providers.

DEFENDANT

8. Upon information and belief, Starent Networks, Corp. ("Starent") is a corporation organized and existing under the laws of the State of Delaware, with a principal place of business at 30 International Place, Tewksbury, Massachusetts 01876. Upon information and belief, Starent conducts business in the State of California and in this judicial district and maintains an office in Walnut Creek, California.

9. Upon information and belief, Starent was founded in August 2000. Upon information and belief, from the time of its founding, certain key Starent employees have come from the CommWorks group acquired by UTStarcom.

10. Gennady Sirota, believed to be one of the four founders of Starent, was a Product Manager at CommWorks before he left in the fall of 2000.

11. Matthew Harper, a named inventor on both of the patents in suit, was a Senior Engineer at CommWorks before he left in September 2000. Upon information and belief, he now works for Starent.

12. Timothy Mortsolf, a named inventor on one of the patents-in-suit, was a Senior Engineer at CommWorks before he left in September 2000. Upon information and belief, he now works for Starent.

13. Steve Williams is a former employee of CommWorks. Upon information and belief, he is currently working for Starent in Walnut Creek, California as a network consultant to one of Starent's customers, Verizon Wireless.

THE PATENTS IN SUIT

14. On May 6, 2003, the United States Patent and Trademark Office duly and legally issued U.S. Patent No. 6,560,217 ("the '217 patent"), entitled "Virtual Home Agent Service Using Software-Replicated Home Agents." UTStarcom has title to the '217 patent. A copy of the '217 patent is attached as Exhibit A to this Complaint.

15. On September 30, 2003, the United States Patent and Trademark Office duly and legally issued U.S. Patent No. 6,628,671 ("the '671 patent"), entitled "Instant Activation of Point-to-Point Protocol (PPP) Connection Using Existing PPP State." UTStarcom has title to the '671 patent. A copy of the '671 patent is attached as Exhibit B to this Complaint.

16. As the owner of the patents-in-suit, UTStarcom has the right to sue and recover for past, present, and future infringement of the patents in suit.

PATENT INFRINGEMENT

17. Upon information and belief, Starent makes, uses, offers for sale, and sells wireless networking technology that enables data, voice, and media services, such as the ST-16 Intelligent Mobile Gateway.

18. Upon information and belief, Starent offers for sale and sells its wireless networking technology equipment, such as the ST-16 Intelligent Mobile Gateway, to wireless

providers including U.S. Cellular, Sprint, Verizon, Rural Cellular Corp., China Unicom, and SK Telecom. Upon information and belief, Starent has deployed its ST-16 Intelligent Mobile Gateway to customers worldwide, including in the United States, Asia, and South America.

19. Upon information and belief, in conjunction with every sale of the ST-16 Intelligent Mobile Gateway, Starent specifically configures the ST-16 Intelligent Mobile Gateway as a specific networking device, such as a home agent or Packet Data Serving Node ("PDSN"), within a mobile communications network. Upon information and belief, Starent further provides instructions and the necessary technical support to its customers to operate the ST-16 Intelligent Mobile Gateway as a specific networking device, such as a home agent or PDSN, within the mobile communications network. Upon information and belief, these Starent activities and services occur both before and after the actual delivery of the ST-16 Intelligent Mobile Gateway to its customers.

20. Upon information and belief, Starent enables, aids, and instructs its customers to further configure and use the ST-16 Intelligent Mobile Gateway.

21. Upon information and belief, Starent has placed at least one ST-16 Intelligent Mobile Gateway as a home agent for testing purposes within this judicial district in Pleasanton, California.

The 6,560,217 Patent

22. Upon information and belief, Starent has offered to configure and is configuring its ST-16 Intelligent Mobile Gateway as a master home agent comprising software replicated home agents.

23. Upon information and belief, Starent, by making, using, offering to sell, and selling its ST-16 Intelligent Mobile Gateway configured with software replicated home agents, has been and is infringing, inducing infringement, and/or contributing to the infringement of one or more claims of the '217 patent.

The 6,628,671 Patent

24. Upon information and belief, Starent's ST-16 Intelligent Mobile Gateway is configured and sold as a network access server.

25. Upon information and belief, Starent, by making, using, offering to sell, and selling its ST-16 Intelligent Mobile Gateway as a network access server, has been and is infringing and/or inducing the infringement of the '671 patent.

Common Infringement Claims

26. As a direct and proximate result of Starent's infringement, inducement of infringement, and/or contribution to infringement of the '217 and '671 patents, UTStarcom has been and continues to be damaged in its business and property, including the loss of substantial profits in an amount to be determined at trial.

27. Upon information and belief, Starent has had actual and constructive knowledge of the '217 and '671 patents, and Starent's infringement, inducement of infringement, and/or contribution to infringement of the '217 and '671 patents has been and is willful and deliberate, rendering this an exceptional case under 35 U.S.C. § 285. Under 35 U.S.C. § 284, UTStarcom is entitled to damages for infringement and treble damages. Under 35 U.S.C. § 283, UTStarcom is entitled to a permanent injunction against further infringement, inducement of infringement, and/or contribution to infringement by Starent.

28. UTStarcom has been and continues to be irreparably harmed by Starent's infringement, inducement of infringement, and/or contribution to infringement of the '217 and '671 patents. Starent's activities of infringement, inducement of infringement, and/or contribution to infringement will continue unless enjoined by this Court.

PRAYER FOR RELIEF

WHEREFORE, Plaintiff UTStarcom respectfully requests that judgment be entered against Defendant Starent as follows:

A. UTStarcom has the right to recover for any and all infringement of the '217 and '671 patents;

B. The '217 and '671 patents are valid and enforceable;

C. Starent has infringed the '217 and '671 patents and such infringement has been willful and deliberate;

D. Starent has induced infringement of the '217 and '671 patents and such inducement of infringement has been willful and deliberate;

E. Starent has contributed to the infringement of the '217 patent and such contribution to infringement has been willful and deliberate;

F. Starent, its officers, agents, servants, employees, parent, subsidiary and affiliate corporations or other business entities, and all other persons acting in concert, participation or privity with them, and their successors and assigns be preliminarily and permanently enjoined and restrained from further infringement, inducement of infringement, and/or contribution to infringement of the '217 and '671 patents;

G. An accounting be had for the damages to UTStarcom arising out of Starent's activities of infringement, inducement of infringement, and/or contribution to infringement together with interest and costs, and that such damages be awarded to UTStarcom;

H. The damage award to UTStarcom be trebled because of Starent's willful and deliberate infringement, inducement of infringement, and/or contribution to infringement;

I. UTStarcom be awarded its attorney fees and expenses in this action as provided by 35 U.S.C. § 285; and

J. UTStarcom be awarded all such other and further relief as the Court may deem just and proper.

DEMAND FOR JURY TRIAL

Plaintiff UTStarcom respectfully requests a trial by jury pursuant to Rule 38(b) of the Federal Rules of Civil Procedure of any and all issues triable of right by a jury.

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CERTIFICATION OF NON-PARTY INTERESTED ENTITIES OR PERSONS

Pursuant to Civil L.R. 3-16, the undersigned certifies that as of this date, other than the named parties, there is no such interest to report.

Dated: March 22, 2004

SHEARMAN & STERLING LLP

By: ______________________________
Vicki S. Veenker

Attorneys for Plaintiff
UTStarcom, Inc.

EXHIBIT A

US006560217B1

(12) **United States Patent**
Peirce, Jr. et al.

(10) **Patent No.: US 6,560,217 B1**
(45) **Date of Patent: May 6, 2003**

(54) **VIRTUAL HOME AGENT SERVICE USING SOFTWARE-REPLICATED HOME AGENTS**

(75) Inventors: **Kenneth L. Peirce, Jr.**, Barrington, IL (US); **Matthew Harper**, Arlington Heights, IL (US); **Timothy G. Mortsolf**, Lisle, IL (US); **Yingchun Xu**, Buffalo Grove, IL (US); **Richard J. Dynarski**, Glen Ellyn, IL (US)

(73) Assignee: **3Com Corporation**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/248,617**

(22) Filed: **Feb. 25, 1999**

(51) **Int. Cl.**^{7} **H04L 12/28**

(52) **U.S. Cl.** **370/351**; 370/601; 709/229

(58) **Field of Search** 370/351, 352, 370/356, 401, 402, 466, 468, 522, 524, 410, 229, 230; 709/229, 225, 224, 250

(56) **References Cited**

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Primary Examiner—Douglas Olms
Assistant Examiner—Ricardo M. Pizarro
(74) *Attorney, Agent, or Firm*—McDonnell Boehnen Hulbert & Berghoff

(57) **ABSTRACT**

Multiple home agents for a home agent service provider network are implemented in a single computing platform in software as multiple virtual home agents. Each home agent is assigned or dedicated to a single virtual private network. Any number of home agents can be realized in the computing platform by multiple instantiations of a home agent program or code, and by providing unique IP addresses for each instantiation. Each home agent runs independently, and is independently configured and managed by the subscriber of the virtual private network service, freeing the service provider of having to manage and supervise low level processing tasks and customization features that the subscribers may want. In a representative embodiment, the computing platform comprises a router having a general purpose-computing platform.

5 Claims, 3 Drawing Sheets

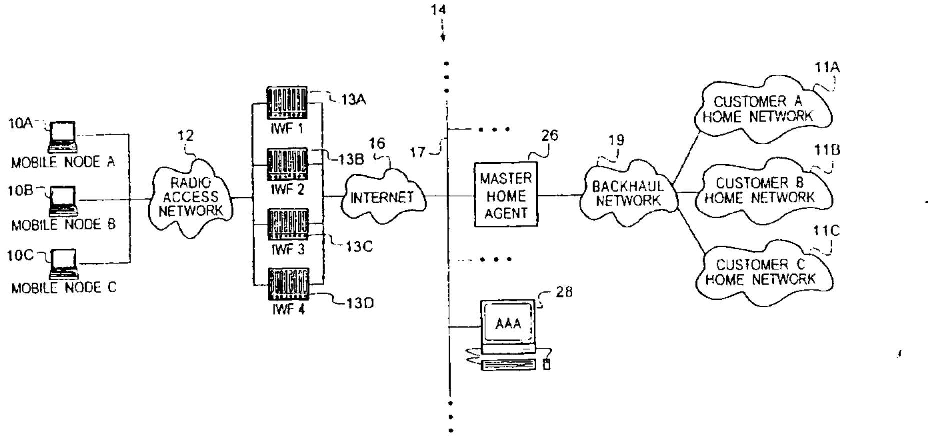
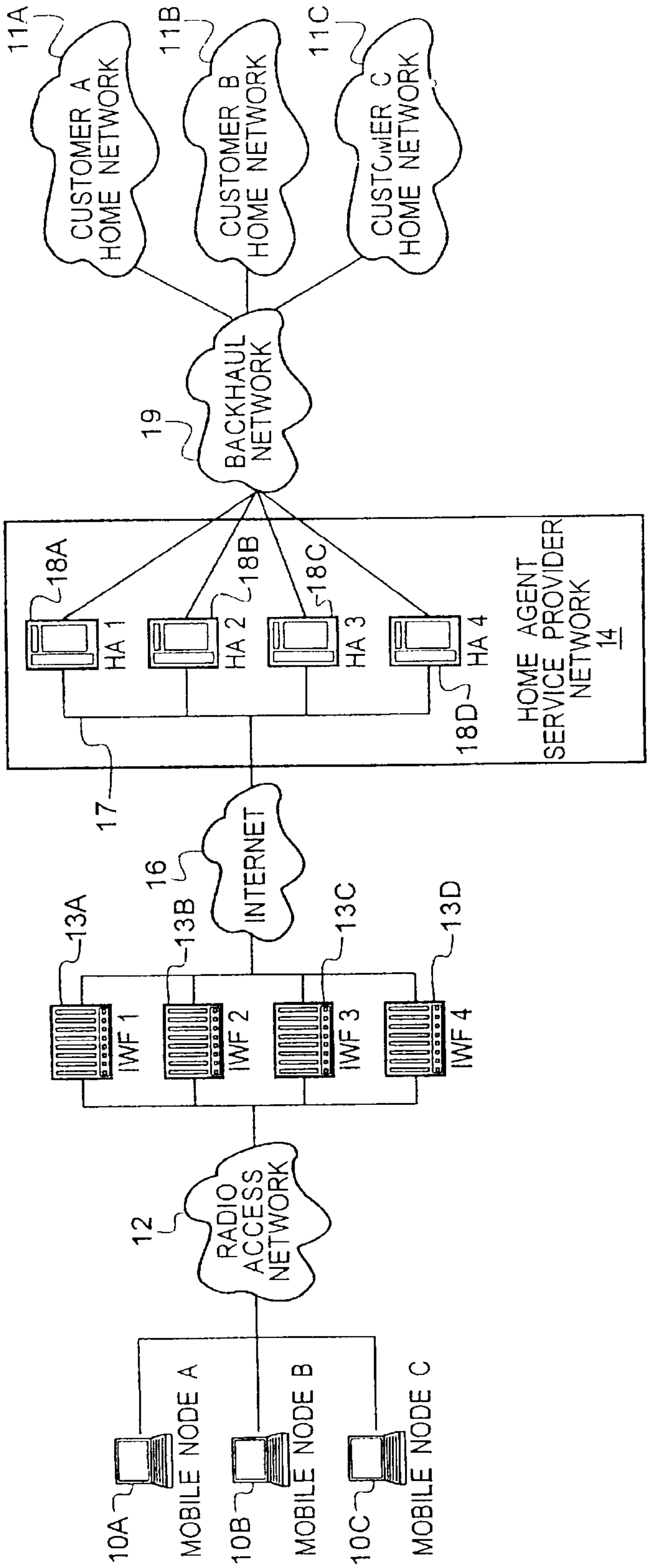


FIG. 1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MOBILE NODE A
10B
MOBILE NODE B
10C
MOBILE NODE C
12
RADIO ACCESS NETWORK
13A
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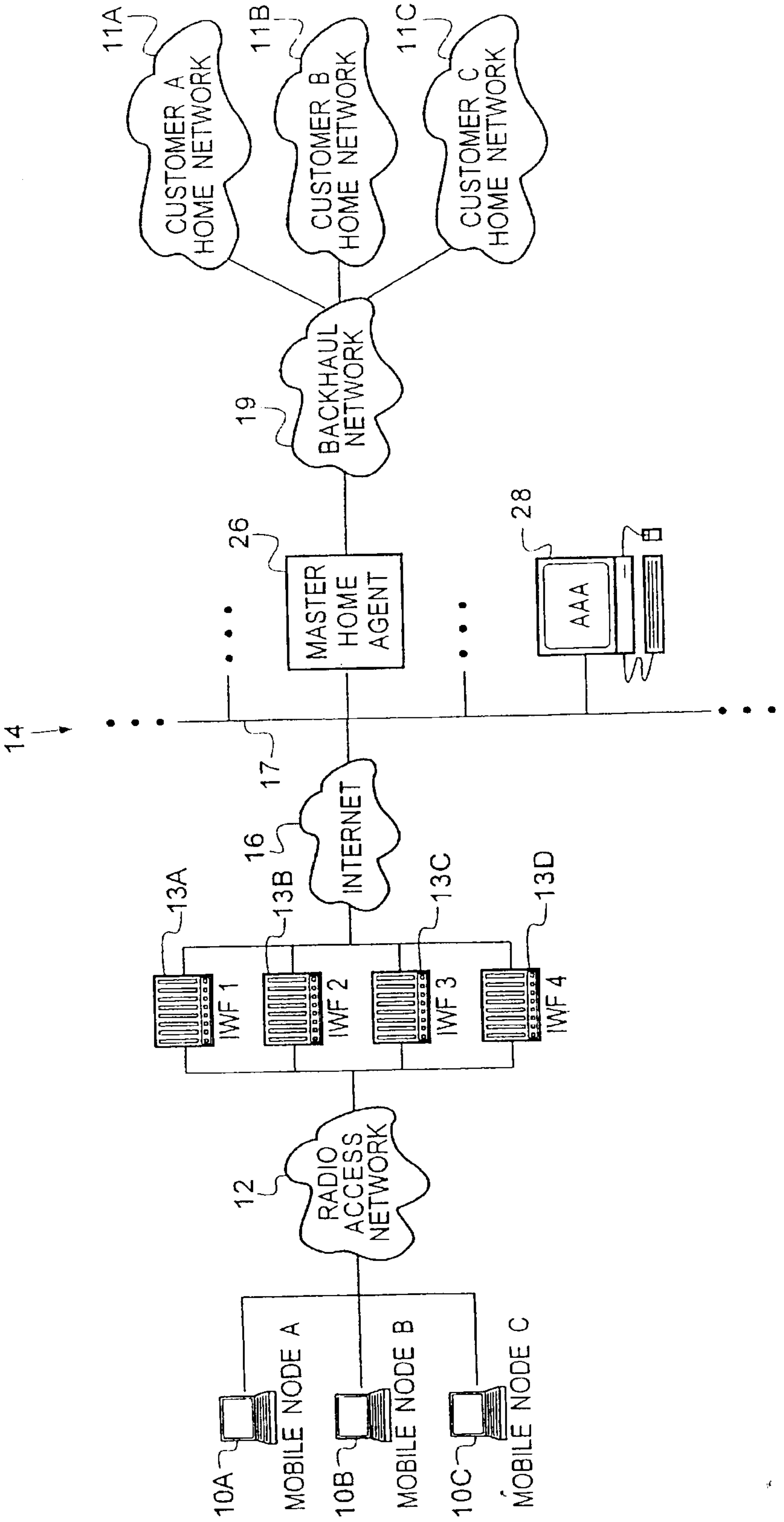
IWF 2
13C
IWF 3
13D
IWF 4
16
INTERNET
17
18A
HA 1
18B
HA 2
18C
HA 3
18D
HA 4
HOME AGENT SERVICE PROVIDER NETWORK
14
19
BACKHAUL NETWORK
11A
CUSTOMER A HOME NETWORK
11B
CUSTOMER B HOME NETWORK
11C
CUSTOMER C HOME NETWORK

FIG. 2


10A
MOBILE NODE A
10B
MOBILE NODE B
10C
MOBILE NODE C
12
RADIO ACCESS NETWORK
IWF 1
IWF 2
IWF 3
IWF 4
13A
13B
13C
13D
16
INTERNET
17
14
26
MASTER HOME AGENT
28
AAA
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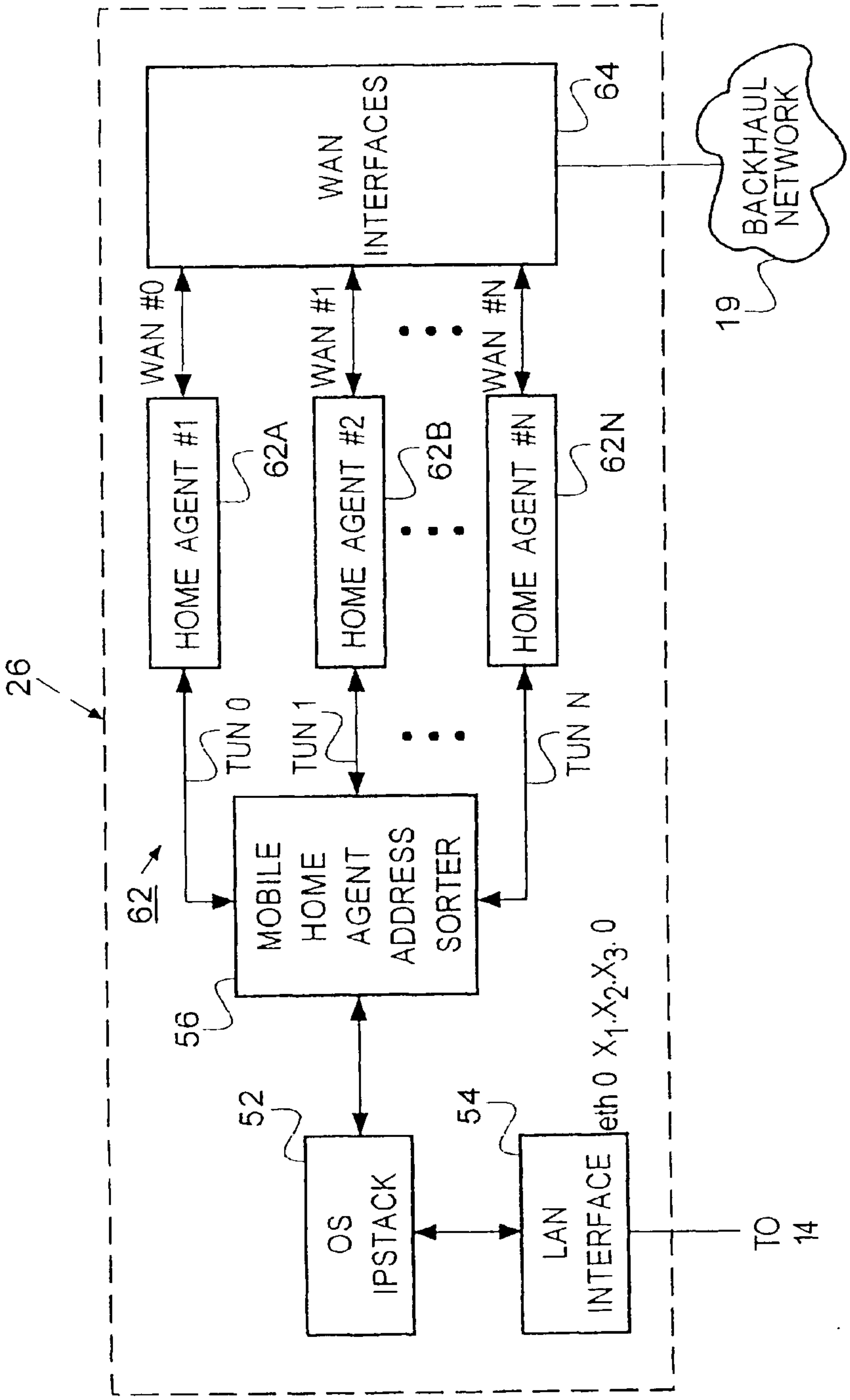
CUSTOMER B HOME NETWORK
11C
CUSTOMER C HOME NETWORK

FIG. 3


26
WAN INTERFACES
64
BACKHAUL NETWORK
19
WAN #0
WAN #1
WAN #N
HOME AGENT #1
62A
HOME AGENT #2
62B
HOME AGENT #N
62N
TUN 0
TUN 1
TUN N
62
MOBILE HOME AGENT ADDRESS SORTER
56
52
OS IPSTACK
54
LAN INTERFACE
eth 0 $X_1.X_2.X_3.0$
TO 14

VIRTUAL HOME AGENT SERVICE USING SOFTWARE-REPLICATED HOME AGENTS

BACKGROUND OF THE INVENTION

A. Field of the Invention

This invention relates generally to the subject of mobile Internet Protocol ("IP") data networking. The invention also relates to the subject of virtual private networking.

B. Description of Related Art

A virtual private network ("VPN") is a service provided by a telecommunications carrier (such as Sprint or AT&T) in which their public network resources are logically organized by the company but managed by the customer, in a manner to provide capabilities similar to those offered by private networks. The concept can be applied to public packet switched networks, e.g., Internet Protocol or Internet Packet eXchange ("IPX") networks. Essentially, a virtual private network is equivalent to a private data network defined logically within a public network, offering the user the economies of scale of the public network, but the control and management capabilities that are found in a private network.

Where a public IP/IPX network supports virtual private networks, then the elements of the network must be configured to handle data traffic for multiple virtual private networks at the same time. For example, a router in the network would have to handle packets for each virtual private network individually, since each virtual private network is managed separately and will typically have its own unique addressing and routing schemes.

Public packet switched networks can be used to carry traffic to and from a mobile communications device, such as a laptop computer or personal digital assistant equipped with a cellular telephone modem. The basic architecture of mobile IP data networking is known in the art and described in several publications, including the Request for Comments document RFC 2002 (1996) and in the textbook of Charles E. Perkins, *Mobile IP Design Principles and Practices*, Addison-Wesley Wireless Communications Series (1998), the contents of both of which are incorporated by reference herein.

Basically, in Mobile IP communication, a wireless mobile node communicates with a terminal on an IP network by means of a foreign agent and a home agent. Typically, foreign agent functionality is incorporated into a router or network access server chassis located on a mobile node's visited network. The foreign agent provides routing services for the mobile node while it is registered with the foreign agent. The foreign agent de-tunnels and delivers datagrams to the mobile node that were tunneled by the mobile node's home agent. The home agent is a router on a mobile node's home network that tunnels datagrams for delivery to the mobile node via the foreign agent when the mobile node is away from home. The home agent maintains current location information for the mobile node, through a variety of possible mechanisms, such as described in the patent application of Richard J. Dynarski, et al., "Dynamic Allocation of Wireless Mobile Nodes Over an Internet Protocol (IP) Network", Ser. No. 09/233,381, which is incorporated by reference herein. When multiple home agents are handling calls for multiple mobile nodes simultaneously, the home agents are providing, in essence, a service analogous to virtual private network services. Each mobile node is typically associated with a separate home network and the routing path from that home network, through the home agent, to the foreign agent and mobile node is like a virtual private network for the mobile node.

The known prior art for providing Mobile IP networking services has embraced the concept of a single home agent for a given network. However, some larger scale providers of Mobile IP networking services may require multiple home agents on their networks. One possible approach is to provide multiple home agents in separate chassis. Another approach is to provide a single home agent, but design the home agent such that it has an internal architecture to support multiple networks (e.g., multiple virtual private networks). This approach is not considered very attractive, in that management of the home agent would be cumbersome. Furthermore, the home agent would not be particularly fault tolerant, in that any mechanical or software problem in the home agent would potentially affect a large number of virtual private networks.

The present invention provides an efficient, easy to manage method for providing a plurality of home agents on a network. All of the home agents are implemented in a single computing platform. That is, rather than attempting to use a single home agent with an internal architecture to support multiple networks, multiple real home agents, each comprising an instantiation of a home agent software program or code, are implemented in the computing platform. Each home agent is dedicated to performing home agent tasks for a single virtual private network. Each home agent is given its own unique address in the computing platform, thereby providing a mechanism for isolating the processing for each home agent from the other processing. The result is an easily managed, scaleable, and fault tolerant mechanism for providing home agent services, particular in high density and large scale implementations of mobile IP.

These and other features of the present invention will be more apparent from the following detailed description of presently preferred embodiment.

SUMMARY OF THE INVENTION

A method for providing home agent services for a plurality of mobile communications devices is provided. The method may be practiced in the context of virtual private network environment, or otherwise. The method makes use of a computing platform (such as a general purpose computer, router, or network access server) that receives a plurality of packets from a first network. The computing platform is configured as a master home agent device, which implements a plurality of real home agents as distinct processing threads in software. For example, the plurality of home agents may comprise multiple instantiations or replications of a home agent software program or process. The packets that are incoming into the computing platform are directed to the home agent that is associated with the packet. This is preferably accomplished by providing each software-replicated home agent with a unique IP address for purposes of directing the packets to the proper home agent.

The packets are processed in the plurality of home agents in accordance with the requirements of RFC 2002 and mobile IP protocols for home agents, or some lesser set of home agent functionality for mobile IP networking if RFC 2002 is not fully supported. For example, the packets may comprise registration request messages from the mobile communications devices. The home agent would then either process the registration request message itself or use an Accounting, Authorization and Authentication (AAA) server to perform some of the processing, such as authentication processing. As another example, the packets may be data packets to be forwarded from the home agent to the mobile communications device. After processing the packet in the home agent, the packets are forwarded onto a second network for transmission to a destination for the packets.

Preferably, in the above method each of the home agents comprise an instantiation of a home agent software program implemented in the computing platform. Further, each instantiation of the home agent software program is given a unique address in the routing chassis. This keeps the processing for each home agent separate from each other. This also makes the system more fault tolerant and more easily managed by known management protocols (SNMP, etc.).

The computing platform or chassis that the above method is implemented may comprises a router, a general purpose computer or any other suitable network element. The main requirement is that it would have a central processing unit and an operating system capable of implementing multiple software-replicated home agents, maintaining separate addresses for each of them, and having the necessary hardware and software interfaces to other communications elements (such as the networks that are used, and possibly an AAA server), in order to provide the desired home agent service for a plurality of mobile communications devices.

The invention is particularly suitable for use in a virtual private network context. The chassis providing the VPN/home agent services would typically be managed by a wireless service provider. Each home agent would be managed separately either by the service provider, or more preferably by the user of that home agent. The exact manner in which the individual home agents would be managed would typically be worked out as a contractual matter between the provider of the chassis and the company it is providing service to. In any event, the segregation of each home agent into separate address space in the computing platform or chassis will allow each home agent to be independently managed.

In another aspect of the invention, a routing chassis processing packets for a plurality of mobile communications devices is provided. The routing chassis comprises an interface to a first network, two or more software-replicated home agents that are running on a computing platform in the routing chassis, and a means (such as a IP stack implemented in a operating system running on the computing platform, or the equivalent) for demultiplexing a plurality of packets arriving from the first network at the first network interface and for forwarding the packets to the plurality of home agents in accordance with addresses contained in the packets. Preferably, each of the home agents comprises an instantiation of a home agent software program.

In a representative embodiment, the routing chassis comprises two or more interfaces to a second network such as wide area network, wherein each of the interfaces to the second network is associated with one of the home agents. The wide area network may for example provide long haul delivery of packets from the mobile communications device to the device's home network. Furthermore, each of the home agents may be associated with a virtual private network.

In yet another aspect of the invention, a method of handing a registration request from a mobile communications device is provided. The method comprises the steps of implementing a master home agent in a communications chassis such as a router or general-purpose computer. The master home agent comprises a plurality of software-replicated home agents. A registration request message is received from the mobile communications device at the communications chassis and forwarded to one of the plurality of software-replicated home agents. The forwarding is

accomplished by reference to an address in the registration request, with each of the software replicated home agents having a unique address.

The software-replicated home agent generates a registration request authentication message and transmits the registration request authentication message to an AAA server. The AAA server either authenticates or does not authenticate the mobile communications device and sends an authentication reply message back to the home agent. The reply is forwarded from the communications chassis to the mobile communications device.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following description, reference will be made to the appended drawings, wherein like reference numbers refer to like elements in the various views, and in which:

FIG. **1** is an illustration of a virtual private network architecture for a plurality of mobile nodes or communications devices, in which home agent functionality for a plurality of networks is spread out among several home agents, each comprising a separate computing platform;

FIG. **2** is an illustration of a virtual private network architecture for a plurality of mobile nodes, in which the functionality of all the home agents of FIG. **1** is combined into a single computing platform, functioning as a router, which is designated a "master home agent." The master home agent implements a plurality of software-replicated home agents.

FIG. **3** is an illustration of the software architecture for the computing platform comprising the master home agent of FIG. **2**, in which up to n software replicated home agents are implemented, each assigned or dedicated to one virtual private network.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

Overview of Representative Virtual Private Network System for Mobile IP Nodes

Referring now to FIG. **1**, a basic architecture for providing IP networking services for a group of mobile nodes is shown schematically. In the example of FIG. **1**, three wireless users, designated **10A**, **10B** and **10C**, send and receive IP packets with host computers on their home networks **11A**, **11B** and **11C**, respectively. The wireless users or nodes send and receive IP packets by means of a radio access network **12** (the details of which are not important) and one of a plurality of network access servers **13A**, **13B**, **13C**, **13D** that function as foreign agents for the wireless devices. The foreign agents **13A** . . . **13D** are on a network maintained by a provider of mobile IP service, such as a wireless communications company or other suitable entity. The network access servers **13A** . . . **13D** are of the general type described in the patent of Dale M. Walsh et al., U.S. Pat. No. 5,528,595 and assigned to the assignee of the present invention. Such network access servers are available from companies such as 3Com Corporation, Ascend Communications, and Lucent Technologies. Basically, the network access servers **13A** . . . **13D** implement foreign agent functions as specified by RFC 2002 and provide access to an IP wide area network such as the Internet **16**.

IP packets for the mobile devices are tunneled to the respective foreign agent by a home agent in accordance with the Mobile IP protocol. In the example of FIG. **1**, the home agent service provider maintains a network **14** including a local area network **17** in which multiple real home agents **18** are located. In the example of FIG. **1**, four such home agents **18**A . . . **18**D are provided. Each home agent comprises a router with an interface to the local area network and a wide area network interface that connects the home agent to a backhaul network **19** (which may be an Asynchronous Transfer Mode network, frame relay network, or other type of network). The backhaul network **19** is in turn connected via suitable routers to the individual home networks **11**A, **11**B and **11**C of the users **10**A, **10**B and **10**C, respectively.

While the architecture of FIG. **1**, and specifically the multiple home agent implementation with multiple discrete chassis is certainly one possible solution for a large scale virtual private network system for multiple mobile IP users, it can be improved upon. With reference to FIG. **2**, we propose consolidating the home agents **18**A . . . **18**D (or more of such home agents) into a single chassis, designated the master home agent **26**. The master home agent **26** serves all of the mobile users **10**A, **10**B, **10**C, etc. and all the virtual private networks that are set up between the mobile users and their home networks **11**A, **11**B and **11**C. Rather than attempt to structure the master home agent **26** with an internal software architecture to support multiple networks within a single home agent process, the present invention provides for implementing, in the master home agent **26**, multiple real, software-replicated home agents, each comprising an instantiation of a home agent software process or program. This will be described in further detail in conjunction with FIG. **3**.

The advantages of multiple real software-based home agents within a single chassis are many. The ease of management, scalability, fault-tolerance, and ease of implementation are perhaps the most striking. Thus, the solution of FIG. 2 is considered a substantial improvement over the alternative organization scheme of FIG. **1**.

Furthermore, in another aspect of the invention, the master home agent **26** takes advantage of an AAA server **28** on the local area network **17** for purposes of registration request authentication processing. This off-loads some of the processing and memory requirements from the master home agent and further facilitates management, accounting and authentication issues for the provider of the virtual private network and mobile IP services. This feature will be explained further below.

Software Architecture of Virtual Home Agent Platform

The master home agent **26** of FIG. **2** consists of a computing platform such as a general purpose computer or router, which is set up with a software architecture and hardware interfaces to function as an home agent for the Mobile IP protocol. As such, it consists of a central processing unit, memory, local and wide area network interface cards and drivers and other hardware (not shown) that will be apparent to a person skilled in the art in view of the present discussion and known router platforms. The details of the hardware are not particularly important. For the purposes of the present invention, the software architecture is the pertinent consideration, and such software architecture is illustrated in FIG. **3**.

The basic concept of the multiple, real, software-replicated home agent is that the master home agent **26** is a computing platform that implements, via software, multiple home agent process or threads **62**A, **62**B, . . . **62**N. Each home agent **62** is an instantiation of a home agent program or code. Each home agent process is responsible for processing only a subset of the hardware interfaces within the complete system, one software replicated home agent designated to one virtual private network, one LAN interface and one wide area network interface.

Each software replicated home agent **62**A, **62**B . . . **62**N is assigned a unique IP address which is used by the operating system (OS) IP stack **52** to demultiplex packets received on the LAN interface(s) **54**. Each home agent process is also connected to a set of Point-Point WAN interfaces **64**, which could be realized by Frame Relay, Asynchronous Transfer Mode (ATM) or any other Point-Point WAN Interface.

This structure allows the master home agent **26** to instantiate any number of multiple different home agents, each one isolated for the other by the operating system in the master home agent. This allows each home agent **62** to be configured differently, and provide different types of home agent services and configurations on a per-VPN basis. Each of the individual home agent instantiations **62**A, **62**B, . . . **62**N are not aware of the different multiple virtual private networks within the master home agent platform; rather, they are simply handling registration requests, authentication and other functions according to their internal configuration.

Additionally, the software architecture of FIG. **3** is much more fault tolerant than prior art approaches. This stems from the feature of separating the individual home agents into different address spaces, and thus different processes. If any one home agent misbehaves, the problem can be fixed or isolated, without affecting any of the other home agents or virtual private networks that are currently active.

The master home agent computing platform of FIGS. **2** and **3** has a LAN interface **54** with an address on the IP/IPX network **14** of the form $X_1.X_2.X_3$.**0**, where X_i is some 3 digit number. The LAN interface **54** receives packets from the IP/IPX network **14** that are designated or belong to any arbitrary number of virtual private networks and home agents. The particular virtual private network to which the packet belongs is determined by an IP address contained in the packet, as discussed below.

The LAN interface **54** forwards packets from the virtual home agent service provider network **14** to an operating system OS IP stack **52** for the master home agent. The operating system in the chassis or master home agent **26** will typically support various communications features, such as an IP protocol stack or software module, of which persons skilled in the art are familiar. The incoming packet from the IP/IPX network **14** will have an IP address associated with one of N possible tunnels, such as $X_1.X_2.X_3$.**1** (tun**0** in FIG. 3). The OP IP stack **52** uses this IP address to demultiplex the packet and select the proper home agent process **62** to process the packet.

For a packet with an address of $X_1.X_2.X_3$.**1**, the packet is routed to home agent process **62**A by a sorting module **56**. The sorting module **56** sorts the packets according to the home agent address in the packet and forwards the packet to the specified home agent process **62**A, **62**B, . . . **62**N (each of which is associated with a unique address). The home agent process **62**A acts as a home agent for virtual private network no. 1 in the present example. The home agent process **62**A serves mobile node A (**10**A) in FIG. **2** and mobile node A's home network

This sorting process further demultiplexes the packet using the information in the IP tunnel header to decide where to route the packet internal to the home agent process **62**A itself. This step allows the home agent process **62**A to terminate certain types of data packets, such as Network

Management packets (using known management protocols such as SNMP, CMIP, etc.), within the individual processes. This step removes the tunneled packet header leaving the original packet to be forwarded/processed.

When the packet is sent to the home agent process **62A**, the home agent functionality as specified in RFC 2002 is performed. The packet is forwarded to a wide area network interface WAN #0 in the WAN interface module **64**. WAN #0 interface is an interface that is assigned or dedicated to the VPN #1 home agent **62A**. The packet is then sent out via the WAN#0 interface for transmission on backhaul network **19** to a terminal on the customer's network **11A**.

For traffic going in the opposite direction, an un-tunneled IP packet arrives on WAN #0 interface, and is forwarded the home agent process **62A**. The home agent process **62A** uses a routing table to determine which foreign agent (e.g., **13A** or **13B** of FIG. **2**) to forward the packet to. The routing table is built from routing packets its receives on either its WAN interface or its tunX interface. It uses this information to build a tunneled IP packet to send via the OS IP stack **52**. The OS IP stack **52** uses the information in the IP header to route the packet to the designated foreign agent, e.g., **13A** of FIG. **2**.

While the process has been described for one home agent **62A** for one virtual private network, it will be appreciated that the process is going on in parallel for multiple virtual private networks in the other home agents **62B**, . . . **62N** in the master home agent **26**. In particular, multiple software-replicated home agents **62A**–**62N** may be instantiated by the operating system at the same time, each one dedicated to its own virtual private network.

Furthermore, since each home agent **62A**, **62B** . . . **62N** is associated with a unique IP address, when the packets are forwarded to the various home agents processes, the information in the IP tunnel header will allow each home agent to terminate management packets, independently of each other, and thus allow each home agent to be separately managed by the VPN subscriber. The management of the separate routing and home agent processes is completely segregated in the master home agent chassis **26** along VPN and home agent customer boundaries. A user of the VPN and its associated home agent can only access and see its own home agent configuration. Additionally, the structure and organization of the master home agent and the network topology of the home agent service provider is completely hidden. This allows the users of the home agent service to be given access to their own home agent process without the need to implement special software to prevent them from accessing or changing another instantiation of a home agent. The entity providing home agent services does not have to be involved in configuration and management of each home agent, as it is left up to the customer. As such, the present invention presents to Mobile IP providers an attractive, flexible and easily managed means for providing home agents for its Mobile IP customers.

From the foregoing, it will be appreciated that we have described a method of providing home agent services for virtual private networks, comprising the steps of:

providing a computing platform (e.g., master home agent **26** or a router in the home agent service provider network) for receiving a plurality of packets from a first network (e.g., IP Network **14**), with the plurality of packets associated with a plurality of different virtual private networks or mobile communications devices;

implementing a plurality of home agents **62A** . . . **62N** in the computing platform;

directing the packets within the computing platform **26** to the home agents **62A**, **62B** etc. associated with the packets;

processing the packets in the plurality of home agents; and

forwarding the packets from the computing platform **26** onto a second network (e.g., WAN **28**) for transmission to the destinations for the packets.

Preferably, each of the home agents comprise a separate instantiation of a home agent software program or code implemented in the computing platform. Further, preferably each home agent is assigned or associated with a unique IP address.

While the multiple software home agents are implemented in a router comprising a master home agent in the illustrated embodiment, it is possible to implement the invention in another type of computing platform.

It will also be appreciated that we have described a processing platform for a plurality of packets associated with a plurality of virtual private networks. The processing or computing platform could be implemented in a general-purpose computer configured with hardware interfaces and suitable software to function as a virtual home agent router, or other suitable device. The processing platform comprises a suitable central processing unit and an operating system program implemented by the central processing unit (e.g., Windows NT). The operating system has as a feature an Internet Protocol (IP) stack. A plurality of home agents comprising multiple instantiations of a home agent program **62A**, **62B**, . . . (FIG. **3**) are implemented in the computing platform. Each home agent is associated with one of the virtual private networks, and each home agent has or is associated with a unique IP address. A plurality of network interfaces **64** (FIG. **3**) are provided in the computing platform that receive the packets from the home agents. The IP stack **52** directs the packets to the home agents **62A**, **62B**, etc. assigned to the packets for processing, and the home agents forward the packets to the network interfaces **64** for transmission to a destination (e.g., a RADIUS server, foreign agent, host computer, etc.).

In a preferred embodiment, each of the home agents are separately configured by a user subscribing to its associated virtual private network service, by means such as SNMP or other management packets that are terminated in the home agent processes **62A**, **62B**, etc.

Further, it will be appreciated that any arbitrary number of software instantiated home agents can be implemented in the computing platform. For example, more than 20 distinct instantiations of the home agent program could be running at one time, each one serving a different virtual private network.

Referring now to FIG. **2**, the use of the AAA server **28** in performing registration request authentication functions for a plurality of mobile nodes will be described. For a mobile node to communicate with its peer in the mobile IP protocol, it must be registered with the foreign agent. During the registration process, the foreign agent (e.g., one of the network access servers **13** of FIG. **2**) sends a registration request message to the home agent for the mobile device. To determine whether the mobile node should be registered or not, the home agent needs to perform an authentication function for the mobile node. This is to insure that only current subscribers are allowed IP network access, and to deny such access where the mobile node has not paid their bill, is no longer a current subscriber, or is otherwise unauthorized to access the service. While the registration request authentication function could be performed entirely within the computing platform in the master home agent chassis, we prefer to have the authentication function carried out in the AAA server **28**. More specifically, information from the registration request (such as the mobile node's IMSI or ESN number, that is, serial number type of information uniquely identifying the device) is forwarded to the AAA server. The AAA server determines from this number whether the mobile node that is seeking registration is authorized or not. The AAA in turn sends a reply indicating the status of the registration request authentication back to the home agent **62** (that is, back to the particular instantiation of the home agent program that sent the authentication request to the AAA server). The home agent then sends back a reply to the registration request message back to the foreign agent, which in turn forwards it to the mobile node. If the registration request is denied, an error code may be included in the reply. Further details on this process are described in the patent application of Richard J. Dynarski, et al., "RADIUS-based Mobile Internet Protocol (IP) address-to-Mobile Identification Number Mapping for Wireless Communication", Ser. No. 09/233401 filed Jan. 19, 1999, the contents of which are fully incorporated by reference herein.

Persons skilled in the art will appreciate that various modifications and alterations from the presently preferred embodiment can be made without departure from the true scope and spirit of the invention. This true scope and spirit is defined by the appended claims, to be interpreted in light of the foregoing.

We claim:

1. A method of handing a registration request from a mobile communications device, comprising the steps of:

providing a master home agent in a communications chassis, said master home agent comprising a plurality of software-replicated home agents;

receiving a registration request from said mobile communications device at said communications chassis and forwarding said registration request to one of a plurality of software-replicated home agents in said communications chassis in accordance with an address in said registration request;

generating a registration request authentication message in said one of said plurality of software replicated home agents;

transmitting said registration request authentication message from said communications chassis to an accounting, authentication, and authorization (AAA) server;

receiving a reply to said registration authentication message from said AAA server at said one of said plurality of software-replicated home agents; and

forwarding a reply to said registration request message from said communications chassis to said mobile communications device.

2. The method of claim **1**, wherein each of said home agents comprise an instantiation of a home agent software program implemented in said communications chassis.

3. The method of claim **1**, wherein said communications chassis comprises a router.

4. The method of claim **1**, wherein said communications chassis comprises a general purpose computer.

5. The communications chassis of claim **1**, wherein each of said home agents are associated with a virtual private network.

* * * * *

EXHIBIT B

US006628671B1

(12) **United States Patent**
Dynarski et al.

(10) **Patent No.: US 6,628,671 B1**
(45) **Date of Patent: Sep. 30, 2003**

(54) **INSTANT ACTIVATION OF POINT-TO POINT PROTOCOL (PPP) CONNECTION USING EXISTING PPP STATE**

(75) Inventors: **Richard J. Dynarski**, Glen Ellyn, IL (US); **Matthew Harper**, Arlington Heights, IL (US); **Andrew Bezaitis**, Chicago, IL (US); **Yingchun Xu**, Buffalo Grove, IL (US); **Kenneth L. Peirce, Jr.**, Barrington, IL (US)

(73) Assignee: **VTStarcom, Inc.**, Alameda, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/233,382**

(22) Filed: **Jan. 19, 1999**

(51) **Int. Cl.**^{7} **H04J 3/22**; H04L 12/56
(52) **U.S. Cl.** **370/469**; 370/389
(58) **Field of Search** 370/466, 467, 370/469, 389, 395.5, 395.52, 401

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WO	WO9901969	1/1999

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International Preliminary Examination Report for 3Com Corporation, et al., in PCT/US99/28016, dated Nov. 16, 2000.

Request for Comments (RFC) 2002, C. Perkins, editor, (Oct. 1996).

* cited by examiner

Primary Examiner—Alpus H. Hsu
Assistant Examiner—Toan Nguyen
(74) *Attorney, Agent, or Firm*—McDonnell Boehnen Hulbert & Berghoff

(57) **ABSTRACT**

A network access server providing remote access to an IP network for a remote client initiates a PPP connection for a remote client quickly, and without requiring re-negotiation of Link Control Protocols and Network Control Protocols. The network access server has a PPP session with the remote client go dormant, for example when the user is a wireless user and goes out of range of a radio tower and associated base station. The network access server does not get rid of the PPP state for the dormant session, but rather switches that PPP state to a new session, such as when the client moves into range of a different radio tower and associated base station and initiates a new active session on the interface to the wireless network. The switching of PPP states may be within a single network access server, or from one network access server to another. This "context switching" of the active PPP session allows the mobile user to seamlessly move about the wireless network without having to re-negotiate Link Control Protocols and Network Control Protocols every time they move out of range of one radio tower and into range of another radio tower.

11 Claims, 6 Drawing Sheets

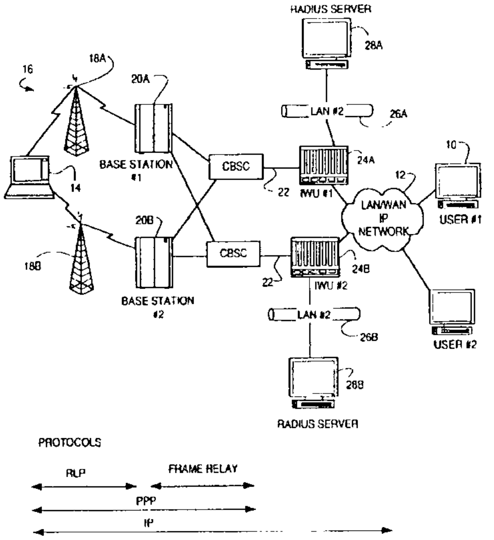


FIG. 1

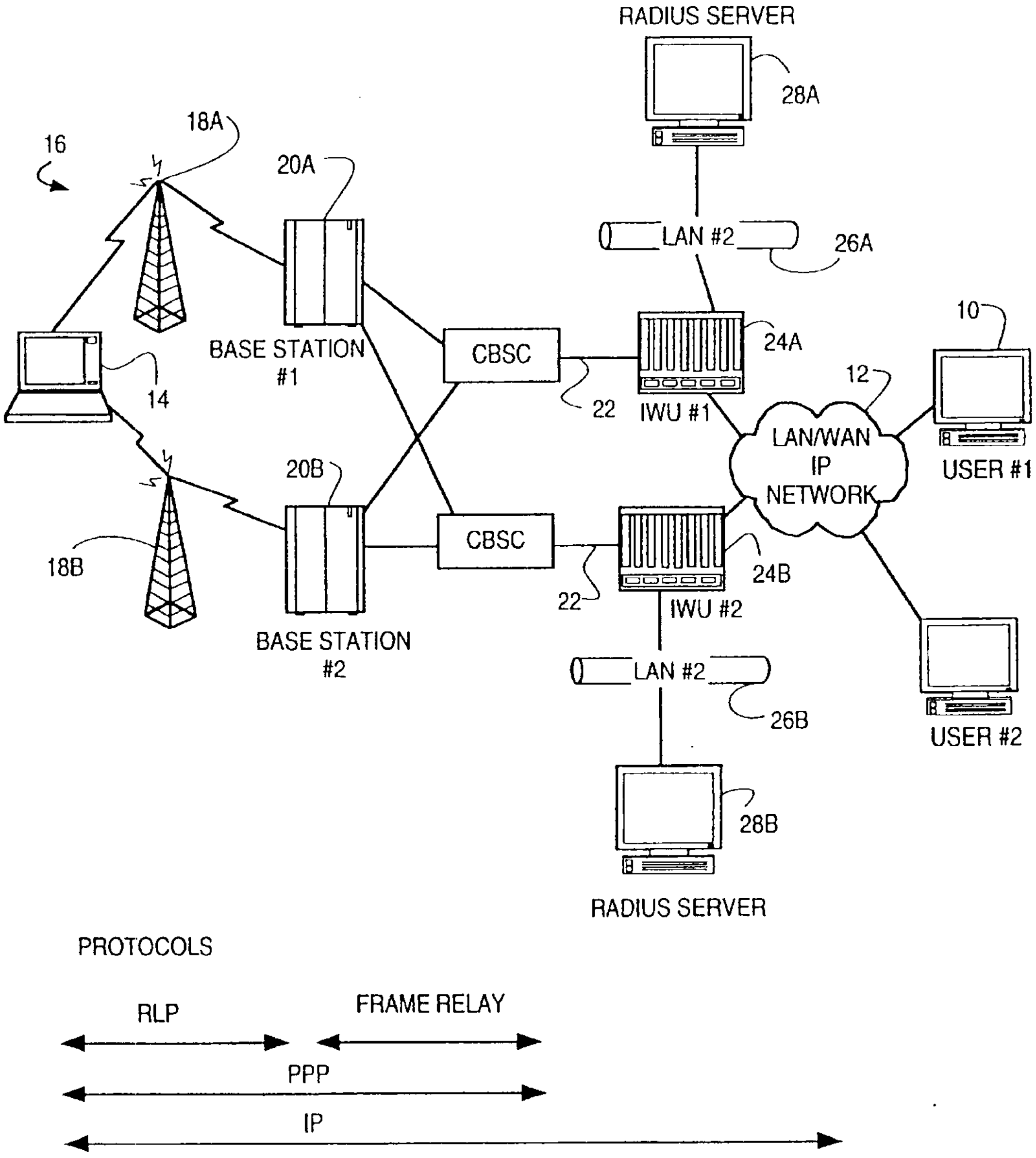
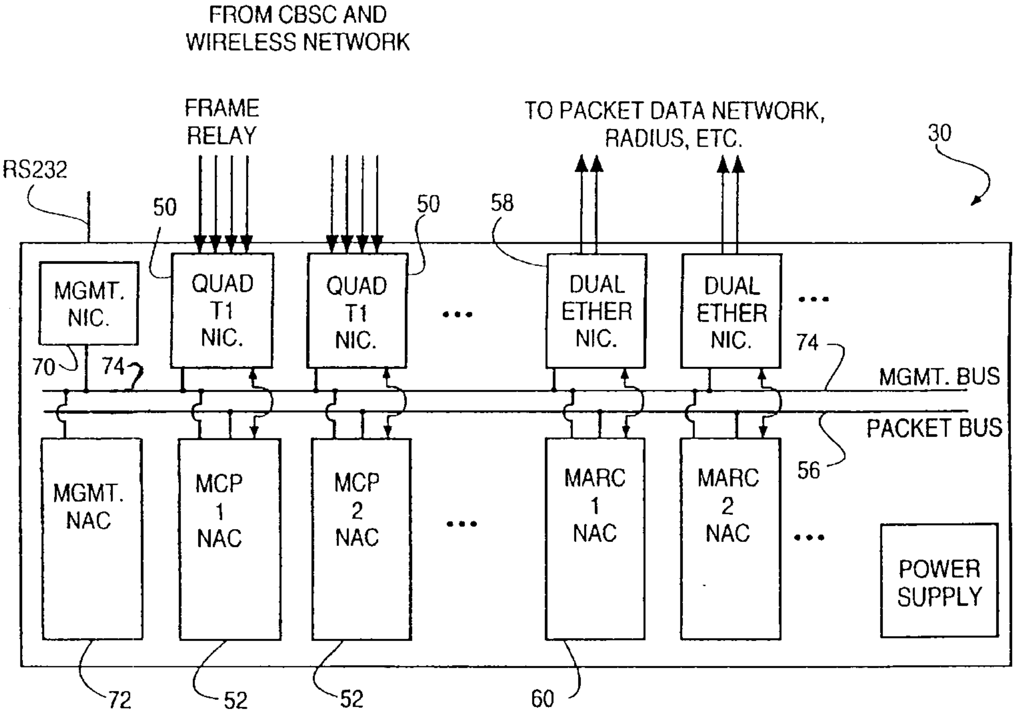

RADIUS SERVER
28A
16
18A
20A
LAN #2
26A
10
24A
CBSC
BASE STATION
#1
14
12
22
IWU #1
LAN/WAN
IP
NETWORK
USER #1
20B
CBSC
18B
24B
22
IWU #2
BASE STATION
#2
LAN #2
26B
USER #2
28B
RADIUS SERVER
PROTOCOLS
RLP
FRAME RELAY
PPP
IP

FIG. 2



IWU = nMCP CARD SETS 50/52+ MARC CARD SET 58/60

FIG. 3

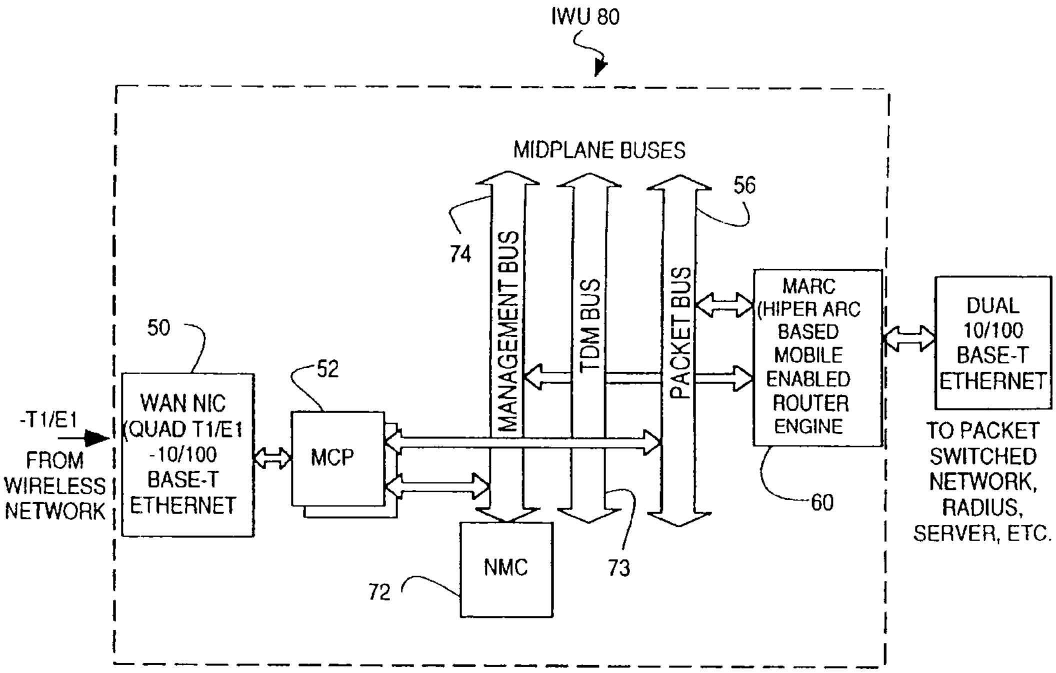

IWU 80
MIDPLANE BUSES
56
74
MANAGEMENT BUS
TDM BUS
PACKET BUS
MARC (HIPER ARC BASED MOBILE ENABLED ROUTER ENGINE
DUAL 10/100 BASE-T ETHERNET
50
52
-T1/E1
FROM WIRELESS NETWORK
WAN NIC (QUAD T1/E1 -10/100 BASE-T ETHERNET
MCP
TO PACKET SWITCHED NETWORK, RADIUS, SERVER, ETC.
60
NMC
72
73

FIG. 4

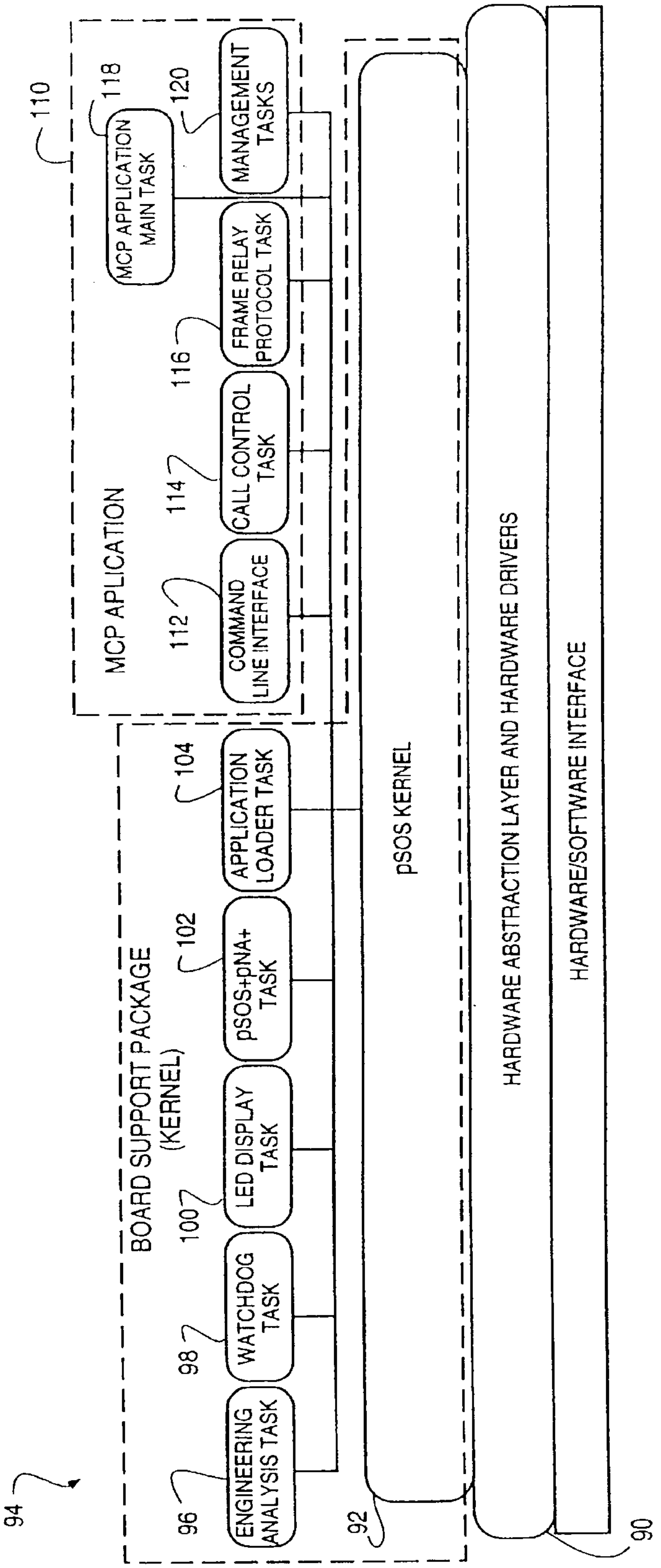

110
MCP APLICATION
118
MCP APPLICATION MAIN TASK
120
MANAGEMENT TASKS
116
FRAME RELAY PROTOCOL TASK
114
CALL CONTROL TASK
112
COMMAND LINE INTERFACE
94
BOARD SUPPORT PACKAGE (KERNEL)
96
ENGINEERING ANALYSIS TASK
98
WATCHDOG TASK
100
LED DISPLAY TASK
102
pSOS+pNA+ TASK
104
APPLICATION LOADER TASK
92
pSOS KERNEL
HARDWARE ABSTRACTION LAYER AND HARDWARE DRIVERS
HARDWARE/SOFTWARE INTERFACE
90

FIG. 5

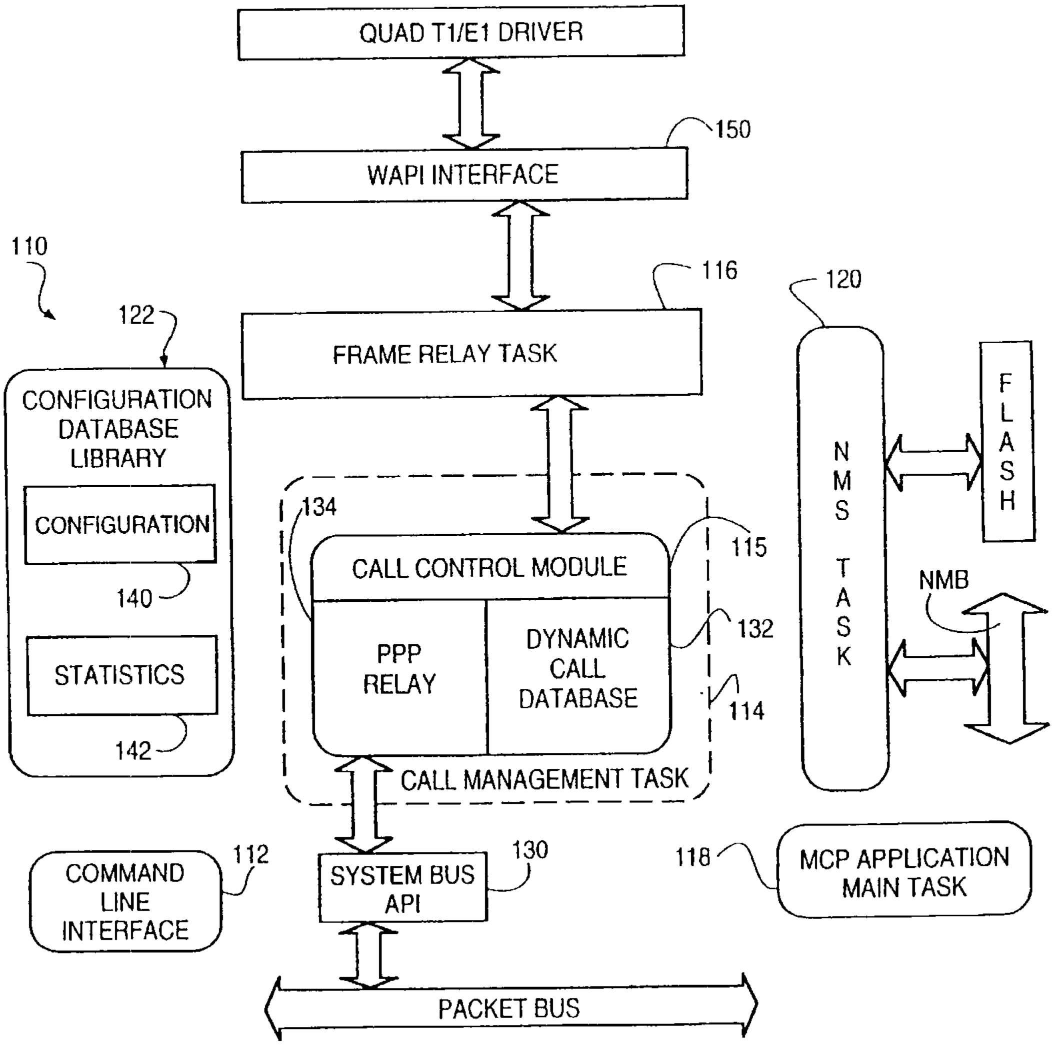
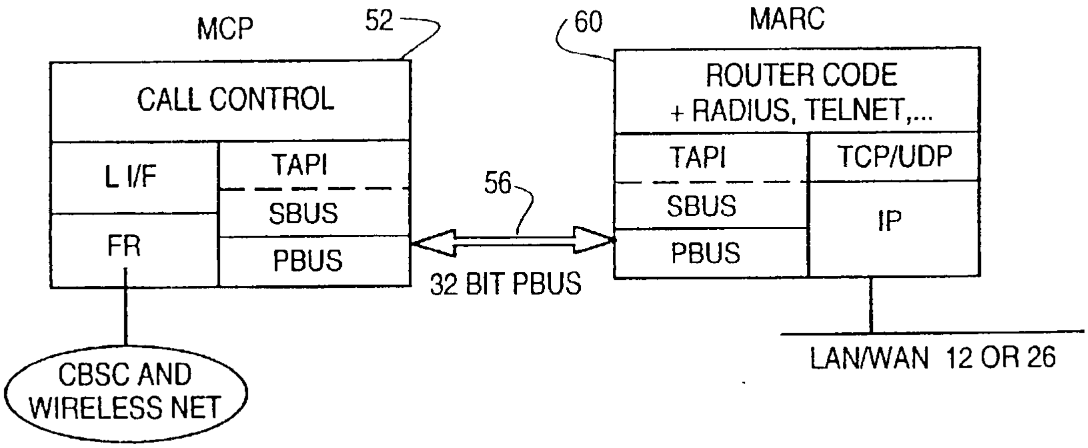

QUAD T1/E1 DRIVER
150
WAPI INTERFACE
110
122
116
120
FRAME RELAY TASK
CONFIGURATION DATABASE LIBRARY
CONFIGURATION
140
STATISTICS
142
134
CALL CONTROL MODULE
115
PPP RELAY
DYNAMIC CALL DATABASE
132
114
CALL MANAGEMENT TASK
N M S T A S K
F L A S H
NMB
COMMAND LINE INTERFACE
112
SYSTEM BUS API
130
118
MCP APPLICATION MAIN TASK
PACKET BUS

FIG. 6


MCP
52
60
MARC
CALL CONTROL
L I/F
TAPI
SBUS
FR
PBUS
56
ROUTER CODE
+ RADIUS, TELNET,...
TAPI
TCP/UDP
SBUS
IP
PBUS
32 BIT PBUS
CBSC AND
WIRELESS NET
LAN/WAN 12 OR 26

INSTANT ACTIVATION OF POINT-TO POINT PROTOCOL (PPP) CONNECTION USING EXISTING PPP STATE

BACKGROUND OF THE INVENTION

A. Field of the Invention

This invention relates to the field of Point-to-Point Protocol (PPP) and Internet Protocol (IP) data networking. More particularly, the invention relates to a process by which a communications device, for example, a laptop computer equipped with a cellular telephone modem, activates a Point-to-Point Protocol (PPP) connection to a Internet Protocol (IP) packet switched network, such as a Ethernet LAN or the Internet, via a network access server. The invention is applicable to other types of PPP links besides a wireless PPP link.

B. Description of Related Art

Wireless communications networks offer much flexibility to the user, in that they allow users of portable communications devices, such as personal digital assistants, laptop computers, telephones, and other appliances to get connected to the public switched telephone network from any location within the region served by the wireless network. Connolly et al., U.S. Pat. No. 5,325,419, discloses a personal communication system by which a mobile device uses an RF link to a communicate with an intelligent base station. The intelligent base station provides radio access along with an Integrated Services Digital Network (ISDN) interface to the public switched telephone network. The PSTN aspect of the system has three components: a personal communications switching center, where telephone central office switches have certain characteristics, a signaling transfer point, and a service control point where an intelligent data base exists maintaining certain user features and records.

The patent application of Yingchun Xu, et al., Ser. No. 08/887,313, now U.S. Pat. No. 6,151,628, which is assigned to the assignee of the present invention and which is fully incorporated by reference herein, describes a system by which a wireless communications device such as a laptop computer may access a packet-switched (e.g., IP) data network such as a corporate backbone network or the Internet. In the Xu et al. system, a frame relay line connected to the wireless network base station couples the remote wireless user to the packet-switched network via an all-digital network access server. This type of network access server can be configured as an InterWorking Unit (IWU) and the two terms are occasionally used interchangeably herein. The network access server provides an interface to the frame relay line and a base station and central base station controller in the wireless network, and an interface (including router functionality) to the packet switched IP network. The Xu et al. application further discloses certain accounting and routing techniques that permit network access to authorized users, while at the same time providing convenient authorization and accounting techniques to be performed by the entity operating the network access server. Network access servers suitable for use as an IWU platform are, per se, known in the art and commercially available from companies such as 3Com Corporation. They are also described in the patent literature. See, e.g., the patent awarded to Dale M. Walsh et al., U.S. Pat. No. 5,528,595, incorporated by reference herein.

In the prior art, every time a call is initiated over a PPP link (such as a call initiated by a remote terminal over the public switched telephone network, over a wireless network, or over some other circuit switched network to a network access server), part of the connection process involves the negotiation of certain protocols with the PPP, such as the Link Control Protocol (LCP), and Network Control Protocols (NCP). Such protocols negotiations are necessary so as to insure that both the remote terminal and the modems or other elements in the network access server are configured in a compatible manner. The many exchanges of parameters during the negotiations and subsequent data transfers contribute to establish a "state" for the PPP protocols to operate within. These protocol negotiations, particularly at the time a PPP link is established, can become time consuming, relatively speaking.

The known prior art has failed to recognize that if a PPP session for a user goes dormant and the user then connects to a different IWU (or to a different port in the same IWU), that the PPP negotiated parameters and the state for a call which is currently going dormant can be used to make the new PPP connection, without repeating the lengthy PPP negotiations. An example of how a PPP session may go dormant is when a mobile wireless communications device moves out of range of a first base station and the call is handed off to a second base station. When a new PPP circuit is established from the mobile device, via the new base station, to the network access server, the network access server/IWU would go through the PPP protocol negotiation procedure in accordance with the prior art approach. In our invention, however, the PPP state from the dormant PPP session (i.e., no active data transfer but the PPP session is still active) is switched over to the new, active PPP session, without requiring re-negotiation of the PPP parameters. Moreover, the switching of the PPP state can occur without the mobile communications device having to disconnect and reconnect it's PPP session. To the mobile unit, it is unaware that its calls have been handed off between base stations and between network access servers/IWUs. Thus, the invention can provide essentially continuous, uninterrupted access to the IP data network regardless of where the user may move within the wireless network.

The invention is especially useful in wireless networks where users with PPP connected mobile units will be continuously moving in and out of range of base stations. However, the same concepts work in any network which provides the ability to connect devices together via the PPP. For example, if a user dials up via the Public Switched Telephone Network (PSTN) and establishes a PPP link with a device such as a network access server, the session goes dormant, and then dials into a different port in the network access server, the PPP state from the dormant session can be used in the new session without the user having to renegotiate the PPP protocols.

An object of the invention is to provide a method to allow a PPP session to go dormant and then dial back into a different port on the same network access server without needing to go through the standard LCP and NCP negotiations to bring the new PPP session active.

In accordance with another feature of the invention, a method is provided to allow a PPP session to go dormant, and then the user dials back into a different port on a different network access server without requiring the user to clean up the previous PPP session on the original network access server.

In accordance with another feature of the invention, a method is provided which allows for call cost accounting for the user during active call periods, as well as during dormant call periods.

These, and other, features and advantages of the invention will be appreciated from the following detailed description of a presently preferred embodiment of the invention.

SUMMARY OF THE INVENTION

A method is provided for connecting a communications device to a packet switched network. The nature of the communications device is unimportant, and could be a personal computer, personal digital assistant, laptop computer with a cellular telephone modem, telephone, or otherwise. The method provides for the step of first initiating a Point-to-Point Protocol (PPP) session between the device and a network access server. The network access server provides access to the packet switched network for the device. The particular medium in which the PPP session is established is not critical. The example of a wireless medium described herein is only one possible example. The session is associated with a PPP state and with a first port in the network access server. As some later point in time, the PPP session thereafter becomes dormant, but the PPP state is not removed from the network access server.

In a first embodiment of the invention, after the PPP session has become dormant, the network access server receives a new call set-up message associated with the communications device. The new call set-up message arrives at a second port in the network access server. In the wireless example, the user operating the lap-top computer moves out of range of one radio tower and into range of another tower, and a call set up message and PPP session is initiated between the new radio tower, base station and the new (second) port in the network access server.

Rather than re-negotiate the PPP protocols (LCP and NCP) for the new session, the PPP state is switched from the dormant PPP session associated with the first port to the session associated with the second port in the network access server. Thus, the PPP state is transferred to the PPP session associated with the new call set-up message and the negotiation of link control protocols or network control protocols between the device and the network access server may be avoided.

In one possible example, the first PPP session becomes dormant due to movement of the communications device relative to a first radio tower linking the device to a wireless communications network. The new call set-up message is initiated in response to the device coming within range of a second radio tower in the wireless communications network.

In one possible embodiment of the invention, the new call set-up message contains information uniquely identifying the device (such as an International Mobile System Identification number (IMSI) and/or Electronic Serial Number (ESN)). The method further comprises the steps of transmitting an access-request message containing this information from the network access server to an authorization server. The authorization server, for example a RADIUS authentication, authorization and accounting server, responsively issues an access-accept message to the network access server if the device is authorized to access the packet-switched network (e.g., the user of the device is a subscriber to the service, has paid its bills, etc.). The network access server then uses the information uniquely identifying the device to identify and find the dormant PPP session associated with the first port in the network access server. For example, the network access server may contain a general purpose computing engine and memory maintaining a table mapping ISMI/ESN numbers to a particular port, with the table indicating whether the particular port is active or dormant. In this fashion, the network access server can avoid re-negotiation of the PPP protocols and instead use the PPP state from the dormant session.

The invention can be used when a connection between the communications device and a second network access server is initiated, while a dormant PPP session exists for the device in the first network access server. In this example, a PPP session is initiated between the device and a first network access server. The first network access server provides access to the packet-switched network for the device. The session is associated with a PPP state and with a first port in the first network access server. The PPP session thereafter becomes dormant but the PPP state is not removed from the network access server.

Thereafter, a second network access server receives a new call set-up message containing information uniquely associated with the device. The new call set-up message arrives at a port in the second network access server. The second network access server transmits an access-request message to an authentication server. The access-request message contains the information uniquely identifying the device, such as the IMSI/ESN number for the device.

The authorization server responsively issues a message to the first network access server to initiate clearing of the dormant session from the first network access server. The first network access server transfers the PPP state for the mobile device to the second network access server. The authorization server further issues an access-accept message to the second network access server. The second network access server responsively enables the negotiation of protocols associated with the PPP, or, more preferably, uses the transfer of the existing PPP state from the first network access server and avoids the re-negotiation of the PPP protocols.

A method is also provided for accounting for wireless communication periods between a mobile communications device and a packet-switched network. The device is coupled to the packet-switched network via a network access server. The method involves tracking time periods in which a communications session between the device and the packet-switched network is dormant. In a preferred embodiment, the step of tracking comprises the step of periodically sending an update message from the network access server to an accounting server. The update message includes information uniquely identifying the device and information indicating the dormant status of the session. The accounting server (e.g., a RADIUS server) monitors the update messages and maintains a log of the amount of time that the session is dormant. Further, the accounting server (or other device in the system providing wireless access to the network) allocates a cost for the dormant time periods. In similar fashion, the accounting server keeps track of the time periods in which the sessions are active, and allocates a cost to the active time periods. The organization operating the network access server and providing wireless access to the network bills the user for both the dormant time periods and the active time periods.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following description, reference will be made to the appended drawings, wherein like reference numbers refer to like elements in the various views, and in which:

FIG. 1 is a schematic illustration of the communications architecture that may be used to link one or more remote terminals on a packet-switched network and a user operating a mobile wireless communications device such as a laptop computer equipped with a cellular telephone modem;

FIG. 2 is a block diagram of a network access server of FIG. 1 in which multiple InterWorking Units (IWU) are implemented within a single chassis;

FIG. 3 is a block diagram of the modules and communications elements in the network access server of FIG. 2 that cooperate to perform the function of a single IWU;

FIG. 4 is a diagram of the application software architecture for the mobile call processor (MCP) card of FIGS. 2 and 3;

FIG. 5 is a further diagram of the software architecture for the MCP card of FIGS. 2 and 3; and

FIG. 6 is an illustration of the protocol architecture that is used for communications between the MCP card of FIG. 2 and the Mobile Access Router Card (MARC) of FIGS. 2 and 3.

DETAILED DESCRIPTION OF THE PREFERRED AND ALTERNATIVE EMBODIMENTS OF THE INVENTION

FIG. 1 is a schematic diagram showing the overall architecture and system by which a user, for example, a person operating personal computer 10 on a corporate backbone or wide area packet-switched network 12, may communicate with a person operating a mobile wireless communications device, such as a user operating laptop computer 14 having a wireless modem for use in a wireless network 16. The wireless network 16 includes one or more radio towers 18A and 18B providing an RF link to a wireless modem in the mobile communications device 14. Each radio tower 18A, 18B has its own base station 20A, 20B, respectively, in the network 16. The details on the wireless network 16 per se are conventional and known in the art. One example would be the personal communications system described in the above-cited Connolly et al., U.S. Pat. No. 5,325,419. Another example would be a conventional cellular telephone network.

The nature of the mobile wireless communications device 14. is not important. For purposes of illustration, a laptop computer with a wireless modem is shown in the drawings. However, it could easily be a personal digital assistant, a portable electronic cash register or credit card swipe with a wireless modem, a portable fax machine, or any other type of device or appliance that can be used to access a packet-switched IP network such as network 12 in order to communicate with a remote terminal such as general purpose computer 10. Of course, the details of the network 12 and remote terminal 10 are also not particularly important.

The base stations 20 are each coupled to a central base station controller (CBSC) via a multiplexed frame relay line 22 which carries data to and from a network access server or InterWorking Unit 24. The CBSC is maintained and operated by the provider of the wireless communication service for the mobile node. The CBSC multiplexes a plurality of calls (e.g., 23) onto an Integrated Services Digital Network Primary Rate Interface (ISDN PRI) T1 line and directs the data to the network access server 24. The CBSC also initiates a page of the mobile node using elements of the wireless network, such as a mobile switching center (not shown), base station 20 A and a radio tower 18A. The connection between the CBSC and the network access server 24 could also use some other technology such as Asynchronous Transfer Mode (ATM). In the embodiment of FIG. 1, both base stations have a frame relay interface that couples the base stations to two network access servers 24A and 24B.

In the illustrative embodiment of FIG. 1, the Point-to-Point Protocol (PPP) is the layer 2 (Data Link Layer) protocol that is used to connect the wireless unit 14 to the network access servers 24. Since it is a layer 2 protocol, it is dependent upon a layer 1 protocol to provide transport over any network. In a wireless network, the Reliable Link Protocol (RLP) is the protocol used between the mobile device 14 and the base stations 18A and 18B.

The base stations 20A and 20B are connected via Frame Relay interfaces to InterWorking Units 24 functioning as Internet Protocol (IP) network access servers. Wireless signaling procedures specify how to establish, remove and idle connections within the wireless network 16, that is, from the mobile device 14 to the InterWorking Unit side 24 of the Frame Relay connection over frame relay lines 22.

The network access servers 24A and 24B provide an interface to the frame relay line 22 and CBSCs. The network access servers 24 have one or more frame relay interface cards (described below) that demultiplex incoming channel data. The network access servers 24 also have one or more Mobile Call Processor (MCP) cards (described below) based on a RISC-based computing platform. The MCP cards forwards packets of digital data from the interface card to a packet bus for transmission to a network interface gateway/router card. The gateway card provides an interface to a packet-switched network such as LAN/WAN 12. In a preferred embodiment, the network access servers are of the type generally described in the above-cited Walsh et al. '595 patent, with the telephone line interfaces modified as necessary to accommodate frame relay lines for transmitting data to and from a wireless communications system indicated generally by reference number 16. Furthermore, since the system is all-digital, modems per se are not needed and the modem cards of the '595 patent can be replaced with a MCP cards as described in further detail below.

Additionally, each network access server 24A and 24B is located on a IP local area network 26A and 26B, respectively. The local area networks 26 include, among other things, an authentication server 28. The authentication server 28, in a preferred embodiment, comprises a general purpose computer functioning as a RADIUS server (a known device) providing accounting, authorization and authentication functions for a plurality of mobile users. Further details on functions performed by the RADIUS server are either known in the art or will be described in more detail below.

With the above overview of FIG. 1 in mind, a method is provided for connecting the mobile wireless communications device 14 to a packet switched network 12 in which a dormant PPP session between the mobile device 14 and a network access server can be used to quickly activate a new PPP session. When the device 14 first dials into the network access server 24A, it initiates a PPP session between the device and the network access server 24A and negotiates components of the PPP, e.g., NCP and LCP protocols. The network access server 24A provides access to the IP packet-switched network 12 and allows the device 14 to communicate with the remote terminal 10. The PPP session between the device 14 and the network access server 24 is associated with a PPP state in the network access server. At some point, e.g., when the device 14 goes out of range of base station 18A, the PPP session thereafter becomes dormant but the PPP state is not removed from the network access server 24A. Again, the PPP state is a set of parameters that include negotiated PPP protocols, the options in use, as well as certain variables that change as the connection exchanges data and PPP control packets. The PPP state for any particular link is a software structure stored in both a gateway or routing card in the network access server 24A that implements the PPP protocol stack, and in the wireless device.

An example of how the first PPP session can go dormant is when the device **14** leaves the range of radio tower **18A** (resulting in the PPP session between device **14**, radio tower **18A** and network access server **24A** going dormant). Specifically, when the mobile device **14** goes out of range of the tower **18A** the base station **20A** signals, using wireless call signaling procedures, to the network access server **24A** that the call is going dormant. The network access server **24A** signals the PPP component (a software module and the PPP stack in the router or gateway card in the network access server **24A**) that the call has gone dormant and the PPP component marks the PPP session as dormant and does not remove its state.

When the device comes into range of radio tower **18B**, a new PPP link is established between the device **14**, tower **18B** and a second port in the network access server **24A** in accordance with a preferred embodiment of this invention. More particularly, the base station **20B** sends a new call set-up message associated with the device **14** to the network access server **24A** via frame relay line **22**, where it is received at a second port in the network access server **24A**. Rather than renegotiate the PPP, LCP and NCP protocols, the present invention takes advantage of the fact that the PPP state for the dormant session can be switched to the new session associated with new call set-up message received at the second port. The PPP state, already established and still existing in the network access server **24A**, is transferred to the session associated with the new call set-up message and the negotiation of link control protocols or network control protocols between the device **14** and network access server **24A** may be avoided.

As noted above, in the illustrated embodiment the first session becomes dormant due to movement of the device **14** relative to a first radio tower **18A**, and the new call set-up message is initiated in response to the device **14A** coming within range of a second radio tower **18B** in the wireless communications network **16**.

In a preferred embodiment, the new call set-up message contains information uniquely identifying the device **14**, such as the device's IMSI/ESN number. The method further comprises the steps of transmitting an access-request message containing this information from the network access server **24A** to its associated authorization server, such as RADIUS server **28A**. The RADIUS server detects that this mobile device **14** is going from dormant to active state because the device's IMSI/ESN has already been allocated an IP address by the RADIUS server **28** (e.g., when the first PPP session was initiated). The RADIUS server **28** responsively issues an access-accept message to the network access server **24A** in the event that the device **14** is authorized to access the network. Further, the network access server uses the information uniquely identifying the device **14** to identify and find the dormant PPP session associated with the first port in the network access server. For example, the RADIUS server **28A** returns an access-accept message with a RADIUS attribute which contains the IMSI/ESN number. That number can be used in the network access server **24A** to find the dormant PPP session (such as by the network access server **24A** maintaining a table mapping IMSI/ESN numbers to PPP sessions).

The network access server **24A** then "context switches" the PPP state from the dormant Point-to-Point Frame Relay interface to the active Frame Relay Point-to-Point interface. The PPP module that is controlling the newly-opened connection has its PPP "state" variables populated with copies of those variables in the dormant PPP session.

After the PPP state has been switched to the active Frame Relay interface (associated with the second port), the network access server **24A** then responds to the base station **20B** with a connect message which brings the RLP/Frame Relay link active so that the mobile device **14** can use the new layer 1 connection. This all happens without the original PPP session or the mobile device **14** having to disconnect and then reconnect its PPP session. The process is transparent to the mobile device, and the user is unaware that its call has been handled off between base stations.

The "context switching" in multiple different network access servers/InterWorking Units is as follows. Still referring to FIG. **1**, a PPP session is initiated between the mobile device **14** and a first network access server **24A**. The PPP session thereafter becomes dormant (e.g., the device **14** moved out of range of the radio tower **18A**), but the PPP state is not removed from the network access server. The network access server **24A** signals the PPP component that the call has gone DORMANT and the PPP component marks the PPP session as DORMANT and does not remove its state.

When the device comes into range of the new tower **18B**, the base station **20B** sends a new call set-up message to the new network access server **24B**, containing information uniquely associated with the device **14**, such as the device's IMSI/ESN number. The new call set-up message is assigned to a certain port in the second network access server **24B**.

The second network access server **24B** transmits an access-request message to its associated authentication server e.g., RADIUS server **28B**. The access-request message contains the information uniquely identifying the device (received in the call set-up message from the base station **20B**). The RADIUS server **28B** responsively issues a RESOURCE-RECLAIM message to the first network access **24A** server to initiate clearing of the dormant session from the first network access server **24A**. The radius server **28B** will know that the first network access server **24A** has a dormant session for the device by virtue of the fact that the Radius Server may be implemented in the same device or chassis as the network access server **24A**, or a discovery packet could be sent by the network access server **24A** to a group of applicable RADIUS servers. Alternatively, the RADIUS server could know that there is a dormant PPP session in the network access server **24A** since it issued an IP address for the mobile device **14** to the network access server **24A**.

The RESOURCE_RECLAIM message allows the IP/IPX routers in network **12** to clear out their routes for the dormant IP address. To accomplish this, the RADIUS server **28B** should either be on the same local area network as the network access server **24A** or be able to route packets there over the LAN/WAN **12**. The RADIUS server **28B** also issues an access-accept message to the second network access server **24B** with the IMSI/ESN number for the device **14** in RADIUS attributes, along with the PPP state variables for the dormant session. The second network access server responsively accepts the PPP state information that accompanies this ACCESS_ACCEPT message and inserts them into the PPP module in its router or gateway card. The process takes approximately 10 milliseconds. This allows for essentially instant activation of the PPP session in the second network access server, all transparent to the user.

It can be seen from the preceding description that we have provided an improvement to a wireless communications system comprising a plurality of radio towers **18A** and **18B** transmitting and receiving data to and from a plurality of mobile wireless communications devices (e.g., **14**), a plurality of base stations **20A** and **20B** linking the radio towers to a high speed digital network (frame relay lines 22), and at least one network access server 24A coupled to the high speed digital network 22. The network access server 24A provides access for the device 14 to an IP packet-switched network, e.g., LAN or WAN 12. The improvement comprises an authentication server 28A coupled to the network access server 24A over a local or wide area network 26. The authentication server 28A contains a suitable software program for processing an access-request message from the network access server 24A when the mobile wireless communications device 14 moves out of range from radio tower 18A into range of radio tower 18B. The access-request message contains information uniquely identifying the device, such as its IMSI/ESN number.

The authentication server determines from the information uniquely identifying the device that this mobile device 14 is going from a dormant to an active state. Specifically, the RADIUS server determines whether an Internet Protocol (IP) address has been allocated to the device (for example, because an IP address was assigned to the the device when it set up its PPP session on one of the ports of the network access server 24A, such session later becoming dormant). The authentication server 28A responsively issues to the network access server 24A an access-accept message containing the IMSI/ESN number indicating that an IP address has been allocated to the device 14. The network access server 24A uses that information to find the dormant PPP session, and switches the PPP state associated with the dormant PPP session to the session associated with the access-request message. Thus, the PPP state may be transferred to the new session and the negotiation of link control protocols or network control protocols between the device 14 and the network access server 24A may be avoided. A similar process can be used for transferring an active PPP state among different network access servers, as described above.

Furthermore, since the RADIUS server 28A is monitoring sessions in which the calls are both active and dormant, it is possible to account for wireless communication periods between a mobile communications device 14 and a packet-switched network 12. The RADIUS server 28A tracks time periods in which the communications session between the device and the network access server 24A is dormant. This can be performed by periodically sending an update message from the network access server 24A to the RADIUS server 28A. The update message includes information uniquely identifying the device and information indicating the dormant status of the session. The RADIUS server (or otherwise by the provider of the service) allocates a cost for the dormant session, such as by minute. Similarly, the RADIUS server tracks time periods in which a communication session between the device 14 and the network access server is active, and allocates a cost for the active time periods. On a regular basis, e.g., once per month, the user operating the device 14 is billed for both the active and the dormant time periods.

Further details on a presently preferred implementation of the invention in an Interworking Unit (IWU) functioning as a network access server will now be described in conjunction with FIGS. 2–6.

FIG. 2 is a block diagram of a network access server 24 of FIG. 1 in which multiple InterWorking Units (IWU) are implemented within a single chassis. The network access server 24 is a high-density system, in that potentially hundreds of calls could be routed through the chassis at the same time. To accomplish this, the chassis consists of a plurality of frame relay line network interface cards 50. Each card 50 is configured to receive four T1 digital telephone lines, comprising twenty four time division multiplexed channels. The 96 channels are demultiplexed in the cards 50 and supplied to an associated Mobile Call Processor (MCP) card 52. The development of circuitry for the Quad T1 NIC cards 50 is within the ability of persons skilled in the art in view of the patent literature (see the above-referenced Walsh et al. '595 patent) or in view of analogous cards present in commercially available network access servers.

The mobile call processor cards 52 basically comprise a RISC-based computing platform that receives the demultiplexed data from the quad T1 NIC, and hands the data in packet form over to low level drivers that place the data on a 32-bit parallel packet bus 56. The packet bus 56 runs down the length of the chassis 24 and provides a means for communication between the various modules in the chassis. The computing platform in the MCP cards may also perform limited PPP co-processing in the manner described in the published European Patent Application of Daniel L. Schoo et al., publication number EP 0 878 070, which is incorporated by reference herein.

The packet data from the wireless network is transmitted along the packet bus 56 to a gateway interface module comprising a dual ethernet network interface card 58 and a Mobile Access Routing Card (MARC) card 60. The MARC card 60 is of the same basic design of the gateway card described in the above-referenced Walsh et al. '595 patent, in that it implements routing code and the associated protocol stacks in order to provide the necessary interfaces to the IAN/WAN IP packet switched data network. Router cards suitable for use as the platform for the MARC cards 60 are also commercially available from companies such as 3Com Corporation in its HiperARC™ routing card and Edgeserver™ card. Equivalent cards are also available from other companies in the industry, including Ascend Communications, Cisco Systems, and Lucent Technologies (successor to Livingston Enterprises, Inc.).

FIG. 6 is an illustration of the protocol architecture that is used for communications between the MCP card of FIG. 2 and the Mobile Access Router Card (MARC) of FIGS. 2 and 3.

In the embodiment of FIG. 2, one set of cards 58 and 60 can support a number of different Quad T1 NIC/MCP card sets 50/52, in that the MARC cards 60 are high capacity cards capable of handling several hundred calls at once. The term IWU, as used herein, is intended to encompass the functionality of a card or device that performs the demultiplexing of the incoming channel data from the frame relay interface, a call processing module, and a gateway interface. It is thus apparent that multiple IWUs can be implemented in a single chassis, such as shown in the embodiment of FIG. 2 in which multiple quad T1 NIC/MCP cards sets and multiple dual ethernet NIC and MARC cards sets are installed in the same chassis.

The chassis of FIG. 2 further includes a management card set 70 and 72 and a management bus 74. The details of these elements are not particularly pertinent to the present invention and thus are omitted. The interested reader is directed to the patent U.S. Pat. No. 5,438,614 to Christopher Rozman et al. for further details on a management system for a network access server.

FIG. 3 is a block diagram of the modules and communications elements in the network access server that cooperate to perform the function of a single IWU 80. The IWU 80 consists of a wide are network interface card 50 providing the interface to the frame relay/T1 line connected to the wireless network, a mobile call processing card 52, and a packet bus 56 coupling the mobile call processing card 52 to the MARC card 60. The network management card 72 and network management bus 74 are optional. Further, while the midplane bus complex includes a time division multiplexed (TDM) bus 73, it is also optional and not necessary or even used in the IWU architecture of FIGS. 2 and 3.

Referring now to FIG. 4, the software architecture of the mobile call processor card 52 is shown. Generally, the software and firmware running in the card includes the following layers: a hardware abstraction layer and device drivers 90, a multi-tasking real time operating system (pSOS+) 92, a board support package 94 comprising an engineering analysis task 96, a watchdog task 98, an LED display task 100, a pSOS+pNA+ task 102, and an application loader task 104. The software further includes an application layer 110, having a command line interface task 112, a call control task 114, a frame relay protocol task 116, an MCP application main task 118, and a management task 120.

Hardware Abstraction Layer and Device Drivers 90

Much of the hardware abstraction layer of the software is resident in a BIOS ROM module in the MCP card. This layer includes the software components that are responsible for initializing the hardware, setting up DRAM, initializing the basic software structures such as the stack and heap, performing general functions such as memory allocation, and accessing peripheral devices.

pSOS+92

This layer is composed of the real-time operating system being used for the MARC and MCP cards. It provides low-latency interrupt and context switching (as described in detail above), task creation and deletion, multitasking, and timer support. For additional information on the pSOS+ operating system, refer to the *pSOSystem Getting Started Manual, pSOSystem Concepts Manual, the pSOSystem User Manuals*, and the *pSOSystem Reference Guide*, available from Integrated Systems, Inc., 201 Moffett Park Drive, Sunnyvale Calif. 94089.

Application Layer 110 and Board support Package 94

These layers include all the tasks running on top of pSOS+ 92. This includes:

Engineering analysis task 96

Application loader task 104

LED display task 100

Watchdog task 98

pSOS+/pNA+ network task 102

The MCP application task 110, consisting of the following tasks: Frame Relay Protocol Task 116, Call Manager Task 114, Management Task 120, MCP Application Main Task 118 and Command Line Interface 112.

Board Support Package 94

The Board Support Package (BSP) 94, also known as the kernel, is software that consists of the engineering analysis task, application loader task, LED display task, watchdog task, and the pSOS+/pNA+ network task. The details on these tasks are not particularly pertinent to the present invention. The kernel also contains utilities/libraries for accessing the flash file system and performing compression, and hardware drivers for serial and Ethernet ports. These utilities are accessible by the MCP application software since it is linked with the kernel's symbol table file.

The MCP application 110 of FIG. 4 will now be described in further detail in conjuction with FIG. 5. The MCP application 110 provides configuration management and call processing functionality such as setup, tear-down, and mobile dormant mode management.

The MCP application is composed of the following components:

MCP Application Main Task 118

Call Manager Task 114

Frame Relay Task/WAN interface 116

Command Line Interface 112

Network management task 120

Configuration management module 122

MCP Application Main Task 118

The MCP core kernel code 104 described earlier loads the MCP application 118 as if it were a single task. This "main" task 118 then oversees the creation of the other application "daughter" tasks (call manager, network management system, and frame relay) and handling of the watchdog timer. Once the daughter tasks have been started, this task has no active role in processing calls or data.

MCP Software Reliability Monitoring (Watchdog Timer Handling)

Once the MCP Application Main Task 118 has created the other tasks, it goes into a loop incrementing the software watchdog counter. This counter is checked periodically by a DSP-resident watchdog task 98 (FIG. 4), which runs at a higher priority than the MCP application 110. The MCP Application Main Task 118 runs at a priority lower than the other tasks; thus the fact that the MCP Application Main Task 118 can bump the software watchdog counter is an indication that the application software is not hung up somewhere. If the watchdog task 98 (FIG. 4) determines that a counter is not being. updated, it begins a series of notifications starting with warnings to the console and concluding with a board restart if the condition persists for a specified period of time. Events are also generated to the network management card 72 (FIG. 2) which result in SNMP traps being sent to the management program for the chassis.

Call Control Task 114

The Call Control Task 114 is basically a relay between the central base station controller (CBSC) in the wireless network and the MARC card. It manages a set of associations between a frame relay task (Frame Relay Switched Virtual Circuit) to the CBSC and a system bus session to the MARC card. Once a path has been established the data is simply relayed between the Frame Relay task 116 and the System Bus (SBUS) Application Program Interface (API) 130.

Dynamic Call Database 132

The Call Control Task 114 maintains a list of dynamic call database (DCD) records. A DCD record is added to the list when a connection is setup with the CBSC and deleted when a session close timer expires or any other disconnect reason (normal or abnormal). Each record contains a collection of information on a per call basis, such as access information into frame relay task for communications with the CBSC, and with the MARC card; session Ids; the Mobile IMSI/

MIN, and ESN numbers for the mobile device; the CBSC Number; a CBSC identifier for the last active packet data session; service configuration identifiers for the last active packet data session; mobility information such as the termination status of the mobile, as defined in section 6.7.1.3.2.4 of TIA/EIA/IS-95-B; Slot Cycle Index—Preferred slot cycle index of the mobile, as defined in section 6.7.1.3.2.4 of TIA/EIA/IS-95-B; the Packet Zone ID—Packet zone identifier of the CBSC that last supported an active packet data session with the mobile, as defined in section 7.7.2.3.2.13 of TIA/EIA/IS-95-B. Additional information that can be contained in the dynamic call database include the session State—Information on the status of a packet data session. The possibilities can be new data session, dormant data session, mobile initiated reactivated data session, and network initiated reactivated data session. Additional information can include:

Link Layer Status—Current status of the link layer connection. The supported values may be active and dormant.

Mobile Reactivation Status—The following parameters shall be used to monitor the status of packet data session:

Paging Status—Supported values shall be active and inactive. The default value shall be inactive.

Backoff Timer—Time to backoff before a retry on an unsuccessful attempt.

Retry Count—Number of retires attempted.

Page Response Timer—Time for the mobile to respond to a Page message.

Call Reference Value—a unique value assigned to each call.

The Dynamic Call Database records will be read-only and accessible through a set of library routines.

Call Control Module—Protocol Engine 115

The Call Control Module **115** (FIG. **5**) handles call setups, tear downs, paging, and general mobile dormant mode management with the CBSC in the wireless network using the interface to the wireless network. The System Bus API **130** provides the signaling mechanism for setting up and tearing down packet data sessions (across the packet bus **56**) with the MARC card **60** (FIG. **2**). Once a packet data path between the CBSC and MARC card is established, the traffic is simply relayed between the two peers. The PPP Relay module 132 discussed in the next section is responsible for relaying the data.

Call Control States

In the call control module **115**, each call has following major states:

IDLE

ACTIVE

DORMANT

The IDLE state represents no call or the call is down.

The ACTIVE state represents the call is up and is able to send/receive data.

The DORMANT state represents the call is up but is not able to transmit data because mobile is in sleep mode. A call needs to be reactivated before sending/receiving data over it. The MARC card buffers data that may have accumulated while dormant. When the call enters the ACTIVE state the MARC card will forward the buffered data to the MCP for transmission to the CBSC in the wireless network.

There are three sub-states of the DORMANT state:

Inactive

Paging

Paged

The Inactive state represents that the mobile is dormant with no paging to the mobile. The Paging state represents that the mobile is dormant and the IWU has sent the setup message to Base Station/Mobile Switching Center in the wireless network. The Paged state represents that the mobile is dormant and the BS/MSC has sent the paging message to mobile.

PPP Relay Module 134

The PPP relay module **134** performs the relay function. A significant performance improvement is realized by having the MCP card do the PPP framing/de-framing and CRC calculations for all PPP packets traversing the path. This feature is described in further detail in the published European patent application of Daniel L Schoo, et al., cited above. The PPP relay function can be enabled/disabled. If disabled the MARC card will perform the CRC calculation and framing/de-framing functions. The PPP offloading state in the DCD record determines whether the MCP performs this task or not.

MCP Hand-over

The MARC card **60** (FIG. **2**) handles hand-overs when the mobile node moves about the wireless network such that new PPP sessions are set up between different MCP cards within the same IWU. The MCP card handles hand-overs when the mobile moves from one T1 interface to another T1 interface on the same MCP NIC card **50** (FIG. **2**). When a call setup message is received from the CBSC via the Frame Relay Task **116**, the Call Control Module **115** performs a database lookup in the list of dynamic call database (DCD) records stored in the Dynamic Call Database **132**. The DCD records are keyed on the IMSI/ESN numbers of the mobile node. If a record is found matching the IMSI received from the mobile and the status of the call indicates that the session is dormant, the Call Control Module **115** will activate the state of the call. A path between the frame relay task **116** and the existing system bus session (which must already exist if an IMSI is found in the DCD) is then established. PPP offloading state procedures and ACCM (negotiated encoding rules for control sequences) are then reapplied to the data path. At this point the data path is opened and the PPP relay module **134** transfers new data packets as usual.

Configuration and Statistics Databases

The Configuration Database Library **122** is a set of routines for accessing and storing configuration and statistics information for the MCP card. This library's main purpose is to abstract the actual implementation of the configuration storage from the tasks that access it. A key design consideration is the ability to accept dynamic configuration changes without affecting current calls. This is accomplished by implementing the concept of working configurations and a separate master configuration. When the configuration changes, only the master configuration is changed.

The configuration database **122** will be configurable at system initialization time and at any other time during the normal operations of the MCP card. The initial system configuration can be downloaded from a management program for the chassis. If no initial configuration download file is available the MCP will boot up with default set of parameters that will allow normal operations in the MCP. The configuration database can also be modified through different mechanisms: SNMP set/get requests via the network management card, Local command line interface over RS-232 port on the MCP network interface card **50** (FIG. **2**), Management program configuration files download via the network management card, and Remote CLI via Telnet passthru mode on MARC card **60**.

MCP Configuration Parameters 140

The configuration parameters **140** of FIG. **5** include a set of configurable parameters, such as a list of the CBSC that are provision, including their number, and operational status.

Statistics 142

The MCP card provides statistics for performance monitoring and alarm generation. The statistics are polled by a management application periodically. Such statistics can include, for example, the number of packet bus frame overruns, packet bus CRC errors, packet bus clock losses, call control statistics, call statistics, such as the accumulated number of mobile originated calls, etc., and the CPU utilization in the MCP card.

Frame Relay Task/WAN Interface 116

The frame relay task provides the frame relay layer between the IWU and CBSC in the wireless network. Layer-2 LAPD I-frames will carry layer-3 T1.617 signaling and layer-3 data traffic.

The IWU supports single out-of-band signaling channel with independent data channels. Each call uses a single B channel for data. There will be only one switched virtual circuit per B channel. This task is also responsible for relaying the accounting information received from the MARC card to the base station and mobile switching center in the wireless network.

Layer 1

The physical layer connecting the MCP card to the wireless network is a T1 PRI with 24 DS0 channels. The first DS0 will be used for running LAPD protocol carrying layer 3 T.617 signaling over DLCI **0**, which is equivalent to TEI **0** and SAPI **0**. The rest of the 23 DS0 channels will be used to carry the mobile path traffic using LAPD UI frame. Each B-channel will be used to carry only one switched virtual circuit's data traffic.

Layer 2

The layer 2 LAPD I-frame will be used to carry layer 3 T1.617 signaling over SVC DLCI **0**. DLCI **0** is mapped to TEI **0** and SAPI **0** in LAPD protocol. The layer 2 LAPD UI frame will be used to carry layer 3 user traffic.

Layer 3

The layer 3 protocol will be T1.617 with specific modifications:

The IWU will use and echo back Channel ID IE coming from SETUP message from CBSC.

1) End to end transit delay element will be echoed back by IWU.
2) Link layer core parameters element will be echoed back by IWU. The layer 3 messages will be carried over layer 2 LAPD DLCI **0**.

WAPI Interface 150

The Wide area network Application Programming Interface (WAPI) is a custom interface for the Quad T1/E1 Network Inface Card **50** (FIG. **2**) driver software. It provides a robust programming interface for allocating and managing resources on the Quad T1/E1 NIC card **50**.

The WAPI **150** externalizes a set of functions that are accessible through the MCPs configuration library **122**. All four facilities on the NIC card **50** can be configured through the configuration library. Each facility can be configured to support different signaling methods including: out-of-band signaling and in-band signaling, and support for fractional T1.

Support for enabling/disabling of resources at a facility and DS0 level is also provided. This can be initiated by the system administrator or by an event occurring in the system indicating a hardware failure.

Features of the MARC Card 60 Software (FIG. 2)

In the illustrated embodiment, the MARC card **60** application is a derivative of the existing software present on the HiperARC router or gateway card of the Total Control Enterprise Network Hub of 3Com Corporation. The MARC card terminates the PPP connections to the mobile station. From the MARC card point of view the MCP cards look like ordinary modems, providing dial-in services. The difference is that the MCP can drop the connection to the mobile and leave the system bus connection over the packet bus to the MARC card established. The system bus session is torn down when any of the following events occur: the MARC receives a session-close timer event from the MCP, the RADIUS client receives a resource-reclaim request from RADIUS server, the MARC card receives a system bus connection request for a mobile that already has an SBUS connection established, or if certain error conditions are present.

Hand-over

The MARC card supports hand-overs by suspending existing system bus connections to MCP cards. A suspended system bus connection means that the connection to the MCP as well as the PPP context associated with it is left open. The connection is kept up until the MCP signals the MARC card to drop it. This can happen in four ways, excluding error conditions:

1) The MCP card session-close timer expires
2) The mobile station application drops its PPP connection
3) an intra-IWU hand-over (hand-over between MCP card) occurs; or
4) an inter-IWU hand-over occurs with the RADIUS server sending a resource-reclaim request to the MARC card.

Hand-overs within an MCP are handle locally by that MCP card (i.e. the MCP will use the same system bus connection it had when the mobile went dormant).

The session-close timer in Internet and Intranet services is the maximum time a mobile can remain in the dormant state. When the timer pops the MCP signals the MARC card resulting in the PPP session being terminated and the system bus connection being released. All resources associated with the connection are reclaimed. The call is released.

The second case is PPP connection dropping. The entire call is removed from existence. The call is released.

In the third case the MCP will signal the MARC that a new call is pending. The MARC card will search its database of IMSIs to determine if a system bus/PPP session already exists for this mobile. If it does the old system bus connection is dropped and a new one is established with the MCP. The existing PPP context or "state" is transferred to the new SBUS connection and PPP traffic flows as if nothing ever happened. This process is described in further detail previously.

In the fourth case a mobile went dormant and then "awoke" at another IWU (i.e., at another MARC card in the chassis or in a different chassis). The RADIUS server will receive an access-request message from the new MARC card. If the RADIUS server determines that the mobile already has authenticated at another MARC, the RADIUS server will send a resource-reclaim to the old MARC and then send an access-accept to the new MARC. This tears down the PPP connection on the old MARC card and establishes a new PPP session from the new MARC card to the mobile. The RADIUS server ensures that the same IP address is assigned to the mobile after moving from one MARC card to another.

IMSI Database

As mentioned above the MARC card must maintain a database of records to support hand-overs between MCP cards. Each record will contain the following: IMSI/ESN numbers, System bus session ID, Usemame and IP address assigned to calling entity.

RADIUS Client

The MARC Card implements a RADIUS client application which will support the standard RADIUS features set forth in Request for Comments (RFC) 2058 and 2059, as well as resource management and interim accounting messaging that includes:

Resource-Query-Request

Resource-Query-Response

Resource-Reclaim-Request

Resource-Reclaim-Response

Nas-Reboot-Request

Interim-Accounting

RADIUS Accounting

All RADIUS accounting is done through the MARC card RADIUS client application. The MARC may require additional accounting message attributes. The exact set of accounting attributes is highly dependent on how billing is done by the wireless service providers, such as whether dormant billing is being performed. The following attributes may be added to the MARC card RADIUS client application:

Active Session (which means the mobile has an active air traffic channel)

Active Session Start Time

Active Session End Time

Active Session Direction (i.e. mobile-originated or mobile terminated)

Active Session Received Byte Count

Active Session Transmitted Byte Count

Interim Accounting

Accounting is started when a new connection is established and stopped when the connection is released. These two messages delimit the entire accounting session. Interim accounting messages are sent on a periodic basis. The MARC card will send the messages every 'X' minutes and the RADIUS server will translate these into start and stop messages.

IWU—Wide Area Push (WAP) Service Support

The IWU architecture of FIGS. 1 and 2 can be used to support a feature by which a terminal on the IP network can initiate a paging of the wireless terminal via the IWU and thereby initiate a communications session with the wireless terminal, without having to have the wireless device be previously registered with the wireless network. In order to support non-registered mobile push services, each service provider will designate one of the deployed IWUs as a master. The master IWU MARC card will sniff all Adresss Resolution Protocol (ARP) requests it receives over the IP network. If the entry is found processing continues as usual. If no entry is found the MARC will send an access-request to the RADIUS server with the username set to IP-Address@domain, where "IP-Address" is the address being sniffed and "domain" is the domain of the WAP Home RADIUS server. The domain is a new configurable parameter set in the master IWU only. The home RADIUS server will return the IMSI and ESN in the call-id and call-number attributes of the access-accept packet. This information is sent to the MCP, which then pages the mobile device via the wireless network.

When the device receives the page, it then knows that a terminal on the IP network is trying to reach it. When the device responds to the page, a connection through the wireless network, an IWU and packet-switched network is initiated. Typically the connection will go through one of the other network access servers on the LAN. The network access server receiving the incoming call from the wireless device notifies a mobile node location server that it has the call (e.g., by an ARP message), providing it with the IP address for the mobile node, and this information is placed in the mapping table maintained by the mobile node location server. The new IP address is forwarded to the home agent to enable the packet from the remote terminal to be routed to the network access server receiving the response to the page. At this point the communication between the wireless device and the terminal on the network may be initiated. The above process is described in further detail in the patent application of Richard Dynarski, filed concurrently, Ser. No. 09/233,381, which is incorporated by reference herein.

Persons skilled in the art will appreciate that numerous modifications may be made to the disclosed embodiments without departure from the spirit and scope of the invention. This true scope and spirit is to found be reference to the appended claims, interpreted in light of the foregoing.

We claim:

1. A method of connecting a communications device to a packet switched network, comprising the steps of:

initiating a Point-to-Point Protocol (PPP) session between said device and a network access server, said network access server providing access to said packet switched network for said device, said session associated with a PPP state and with a first port in said network access server, wherein said PPP session thereafter becomes dormant but said PPP state is not removed from said network access server;

receiving, after said PPP session has become dormant, at said network access server a new call set-up message associated with said device, said new call set-up message arriving at a second port in said network access server;

switching said PPP state from said dormant PPP session associated with said first port to a session associated with said new call set-up message associated with said device at said second port,

wherein said PPP state is transferred to said session associated with said new call set-up message and the negotiation of link control protocols or network control protocols between said device and said network access server may be avoided.

2. The method of claim 1, wherein said PPP session becomes dormant due to movement of said device relative to a first radio tower linking said device to a wireless communications network, and wherein said new call set-up message is initiated in response to said device coming within range of a second radio tower in said wireless communications network.

3. The method of claim 1, wherein said new call set-up message contains information uniquely identifying said device, and wherein the method further comprises the steps of:

transmitting an access-request message containing said information from said network access server to an authorization server;

said authorization server responsively issuing an access-accept message to said network access server; and

said network access server using said information to identify and find said dormant PPP session associated with said first port in said network access server.

4. A method of connecting a communications device to a packet switched network, comprising the steps of:

initiating a Point-to-Point Protocol (PPP) session between said device and a first network access server, said first network access server providing access to said packet switched network for said device, said session associated with a PPP state and with a first port in said first network access server, wherein said PPP session thereafter becomes dormant but said PPP state is not removed from said network access server;

receiving, after said PPP session has become dormant, at a second network access server a new call set-up message containing information uniquely associated with said device, said new call set-up message arriving at a first port in said second network access server;

transmitting an access-request message from said second network access server to a authentication server, said access-request message containing said information uniquely identifying said device;

said authorization server responsively issuing a message to said first network access server to initiate clearing of said dormant session from said first network access server; and

said authorization server further issuing an access-accept message to said second network access server, said access-accept messaging containing information as to said PPP state retrieved from said first network access server,

said second network access server responsively configuring a new PPP session with said device with variables from said dormant PPP session.

5. The method of claim 4, wherein said PPP session becomes dormant due to movement of said device relative to a first radio tower linking said device to a wireless communications network, and wherein said new call set-up message is initiated in response to said device coming within range of a second radio tower in said wireless communications network.

6. In a wireless communications system comprising a plurality of radio towers transmitting and receiving data to and from a plurality of mobile wireless communications devices, a plurality of base stations linking said radio towers to a high speed digital network, and at least one network access server coupled to said high speed digital network, said network access server providing access for said devices to a packet switched network, an improvement comprising;

an authentication server coupled to said network access server over a local or wide area network, said authentication server:

(a) processing an access-request message from said network access server when a mobile wireless communications device among said plurality of mobile wireless communications devices moves out of range from a first radio tower amongst said plurality of radio towers and into range of a second radio tower amongst said plurality of towers, said access-request messages containing information uniquely identifying said device;

(b) determining, from said information, whether an Internet Protocol (IP) address has been allocated to said device, and

(c) responsively issuing to said network access server an access-accept message containing said information in the event that an IP address has been allocated to said device,

wherein said network access server may use said information to find a dormant PPP session associated with a communication between said network access server and said device via said first radio tower amongst said plurality of towers and switch a PPP state associated with said dormant PPP session to a session associated with said access-request message;

whereby said PPP state may be transferred to said session associated with said access-request message and the negotiation of link control protocols or network control protocols between said device and said network access server may be avoided.

7. The method of claim 1, further comprising:

tracking dormant time periods in which said PPP session associated with said first port and a PPP session associated with said new call set-up message are dormant;

allocating a cost for said dormant time periods;

tracking active time periods in which said PPP session associated with said first port and said PPP session associated with said new call set-up message are active;

allocating a cost for said active time periods; and

billing a user operating said communications device for said dormant time periods and said active time periods.

8. The method of claim 7, wherein tracking dormant time periods comprises:

sending periodic update messages from said network access server to an accounting server, wherein said update messages include information uniquely identifying said communications device and information indicating a status of a respective dormant PPP session.

9. The method of claim 7, wherein said network access server is coupled to said accounting server via a local area network.

10. The method of claim 7, wherein said accounting server comprises a RADIUS server.

11. The method of claim 7, wherein the packet switched network comprises an Internet.

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